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BIOLOGICAL SURVEY—BULLETIN No. 31

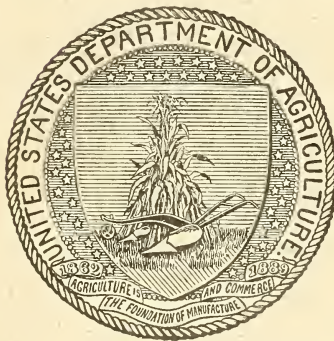
W. HART MERRIAM, *Chief*

AN ECONOMIC STUDY OF FIELD MICE
(GENUS *MICROTUS*)

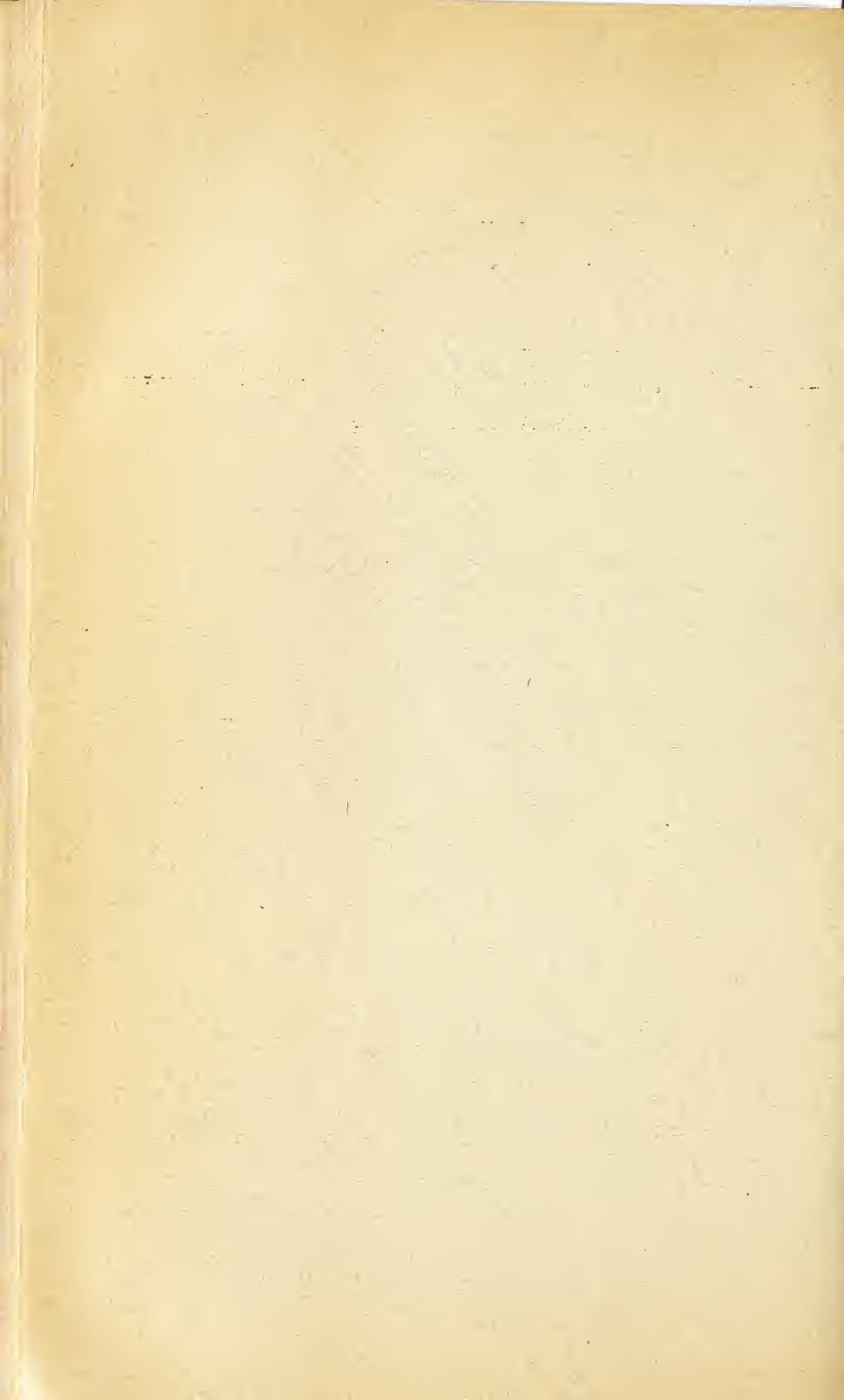
BY

DAVID E. LANTZ

ASSISTANT, BIOLOGICAL SURVEY



WASHINGTON
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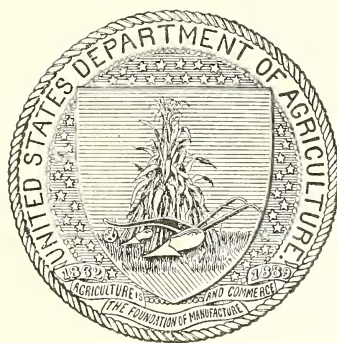
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BIOLOGICAL SURVEY,

Washington, D. C., August 1, 1907.

SIR: I have the honor to transmit herewith, as Bulletin No. 31 of the Biological Survey, an economic study of field mice, by David E. Lantz. Field mice are so generally distributed throughout the United States and at times are so numerous in certain regions that they do serious damage to gardens, nurseries, orchards, and forests. The several species therefore possess an economic importance quite out of proportion to their size. The present bulletin gives a concise account of their distribution and general habits, the nature of the damage they do, together with methods of prevention, the best means of limiting their increase under ordinary circumstances, and of reducing their numbers when, by reason of excessive multiplication, the injuries they inflict are serious.

Respectfully,

H. W. HENSHAW,
Acting Chief, Biological Survey.

HON. JAMES WILSON,

Secretary of Agriculture.

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AN ECONOMIC STUDY OF FIELD MICE.^a

INTRODUCTION.

The present paper deals with the habits of the common field mice ^a of the United States, the conditions which often favor their enormous multiplication, the natural enemies which aid in their repression, and the agencies which farmers may employ to avoid losses by the animals. Small as these pests are, they inflict enormous injury upon the crops of the country. The aggregate loss to the farmers from this source averages not less than three millions of dollars annually, and in some years is much greater. The major portion of this loss is preventable, and the object of this bulletin is to acquaint farmers, orchardists, nurserymen, and others with the most practical preventive methods.

Among the more interesting facts connected with wild animals are the sweeping changes in the relative numbers of certain species to be noticed from year to year in almost every locality. Species that are abundant one season may be rare or entirely absent the next; or they may gradually increase or decrease in numbers through a series of years until disaster results from their overabundance, or the species becomes practically extinct. Sometimes wild animals increase in numbers so suddenly that the change has been likened to a tidal wave, and ignorant people have regarded the invasion as of miraculous origin. The belief that crickets, locusts, frogs, and even mice sometimes fall from the clouds is still held in many countries.

The careful observer, however, sees little mystery in the phenomena mentioned. He has studied the general habits of animals—their food, their powers of reproduction, their migrations, the checks on their increase due to natural enemies, disease, and varying climate—and consequently he attributes sudden changes in their numbers to known causes. In such changes he recognizes, especially, the influence of man, both direct and indirect, and his responsibility for interferences that greatly modify the operations of nature.

^a The term "field mice" applies equally well to several groups, or genera, of mice which occur in cultivated areas and meadows of the United States, but in this paper it is restricted to the most widely known group, the genus *Microtus*.

Outside the insect world the most striking examples of occasional excessive multiplication of a species are afforded by rodents. The invasions of rabbits and rats are familiar, but no rodents exhibit the tendency more forcibly than the *Microtinae*, a subfamily which includes lemmings, voles, and muskrats. The lemmings and voles, especially, are noted for those peculiar waves of increase that astonish observers and bring disaster in their wake. The most noted example is afforded by the somewhat periodic migrations of lemmings (*Lemmus lemmus*) in Norway and Sweden.

These animals live in the higher plateaus of Scandinavia. Here during several favorable years they increase in geometrical ratio until the food supply gives out and hunger impels great hordes to migrate into the lower valleys. Once started on their journey they continue in the same general direction in spite of all obstacles. They travel in vast armies, swimming lakes and streams, living on the products of the soil, and carrying calamity to farmers. They breed on the journey, lingering only until the young are strong enough to travel or until food is exhausted. They are constantly the prey of natural enemies which gather in their wake, and are destroyed ruthlessly by man; so that in spite of an enormous natural increase, the vast army gradually melts away. Usually disease breaks out and helps to decimate them, so that as a rule comparatively few reach the final barrier to their march, the sea. After a short delay the survivors, ignorant of the nature of the barrier, plunge into the water and essay its passage, swimming until they perish.^a The migrations usually cover a period of two years, but are sometimes prolonged to three. None of the migrating animals return to their homes, and they are entirely absent in the lower valleys until the next migration.^b

The economic vole (*Microtus oeconomus*) of Siberia performs somewhat similar migrations. Writing of it over a century ago Thomas Pennant said: "They in certain years make great migrations out of Kamtschatka; they collect in the spring and go off in incredible multitudes. Like the *Lemmus*, they go in a direct course and nothing stops their progress, neither rivers or arms of the sea: in their passage they often fall a prey to ravenous fishes and birds, but on land they are safe, as the Kamtschatkans pay a superstitious regard for them; and when they find them lying weak or half dead with fatigue on the banks, after passing a river, they will give them

^a Prof. Robert Collett, of Christiania, Norway, records that in November, 1868, a steamer sailed for a quarter of an hour through a swarm of lemmings which extended as far as the eye could reach over the Trondhjemsfjord. (Journal Linnean Society of London, Vol. 13, p. 33, 1878.)

^b T. T. Somerville, Proc. Zool. Society of London, 1891, pp. 655-658. Robert Collett, Journal Linnean Soc. of London, Vol. 13, pp. 327-334, 1878.

all possible assistance. They set out in their migration westward. From the river Penguin they go southward and about the middle of July reach Oshotska and Judoma, a tract of amazing extent. They return again in October. The Kamtschatkans are greatly alarmed at their migrations, as they presage rainy seasons and an unsuccessful chase; but on their return, expresses are sent to all parts with the good news."^a

Visitations of voles have not been infrequent in the history of the Old World. The earliest records of them are in the Bible^b and in the works of Homer, Herodotus, and Aristotle. So serious did the Greeks consider plagues of field mice that in their pantheism they had a mouse god (Apollo Smintheus), who was invoked to avert the evil.

Invasions of field mice have not been rare in Great Britain and the Eurasian continent. Blasius records serious outbreaks on the Lower Rhine in the twenties.^c Brehm, quoting Lenz, gives an account of one in 1856 and of another in Rhenish Hesse in 1861. Brehm himself observed hordes of the animals in 1872 and 1873 on the sandy plains of Brandenburg and in the rich corn lands of Lower Saxony, Thuringia, and Hesse.^d The chroniclers of England—Holinshed, Stow, Childrey, Lilly, Fuller, and others—record outbreaks of mice in Essex and Kent, 1581, and again in Essex in 1648 and 1660. Later plagues occurred in parts of England in 1745, 1754, 1814, 1825, 1836, and 1863–1867. Severe outbreaks took place in Scotland in 1825, 1864, 1876, and 1892, the last so serious in its effects upon the sheep industry that the British Board of Agriculture appointed a special committee to investigate it. The report of this committee^e is the most complete and important contribution to our knowledge of field mice thus far published.

A large portion of Hungary was devastated by field mice in 1875 and 1876. In 1875 they were observed to be very numerous in certain districts, and by the spring of 1876 they fairly swarmed in cultivated fields, so that the peasants "doubted whether they had sprung from the earth or fallen from the clouds." They devoured grain, roots, and growing vegetation—corn, potatoes, turnips, and lucern. In the fall they attacked vineyards and shrubbery, and

^a History of Quadrupeds, by Thomas Pennant, 3d edition, vol. II, p. 195, 1793.

^b "And the cities and fields in the midst of that region produced mice and there was great confusion and dearth in the city." I Samuel, v., 6 (Vulgate version.)

^c Naturgeschichte der Säugethiere Deutschlands, von Johann Heinrich Blasius, p. 386, 1857.

^d A. E. Brehm, Thierleben: Säugethiere, vol. 2, p. 390, 1877.

^e Report of the Departmental Committee on a Plague of Field Voles in Scotland, London, 1893.

when food was exhausted, began to eat each other. They were finally destroyed by an infectious disease, which killed them by thousands.^a

In North America, up to the present time, no such calamitous invasions of field mice have been known, although occasionally one or another species increases locally to such an extent as to amount to a plague. Of even greater consequence, however, is the steady drain on agricultural products caused by these rodents over a large part of the country when present in normal numbers.

CLASSIFICATION OF FIELD MICE.

The genus *Microtus* belongs to a subfamily of *Muridae* known as the *Microtinæ* (formerly *Arvicolinæ*). This subfamily embraces a large number of forms of small and very similar rodents which in some respects resemble true mice, but which are readily distinguished by the robust body, thick head, short ears (whence *Microtus*), and short tail, the last exceeding two-thirds of the length of the body in but one genus, *Fiber* (muskrats).

The *Microtinæ* are divided into two groups, which are commonly distinguished under the names lemmings and voles. Externally lemmings have shorter bodies than voles, and, except in one genus (*Synaptomys*), the tail is shorter than the hind foot, and the palms and soles are without distinct foot pads (plantar tubercles). The two principal genera have the nails on the thumb strap-shaped (ligulate).

Voles have bodies less stout, tails usually longer than the hind foot, and soles and palms always with distinct foot pads. The thumb nails are pointed, not ligulate. There are four genera of voles, all having representatives in the United States, of which the two more familiar are *Fiber* (the muskrats) and *Microtus* (the field mice). The other two genera are of little importance to the farmer. The present paper deals only with the genus *Microtus*.

Voles of the genus *Microtus* are distinguished from members of the other three genera by having rootless molars at all stages of their life. *Fiber* may easily be recognized by its large size, its long, laterally flattened tail, and by its having the feet modified for swimming.

There seems to be no entirely appropriate vernacular name for the mice of the genus *Microtus*. The French call them "campagnols," the Germans "wühlmäuse." English-speaking people outside the United States call them "voles." In the United States they are variously designated as "meadow mice" or "field mice," and locally as "bear mice," "bull mice," "buck-tailed mice," "mole mice," etc. "Vole" is open to the objection that it applies equally well to three other genera and may easily be confused with "mole." "Field mice"

^a Report on a Plague of Field Voles in Scotland, Appendix III, p. 76, 1893.

will apply as well to other genera and subfamilies of mice, while the term "meadow mice" is not broad enough to include all the species of *Microtus*.

SPECIES AND DISTRIBUTION.

Field mice of the genus *Microtus* have stout bodies, blunt, rounded muzzles, small eyes, and short ears—often completely concealed in the fur. The tail is short and hairy; the soles of the feet are naked or clothed with short hairs, and have five or six foot pads (plantar tubercles). The incisors are broad and not grooved.

The molar teeth in all members of the genus, like the incisors of all rodents, grow continuously throughout the life of the animal and do not develop roots. They are prismatic in form, and the crowns show triangular dentinal spaces surrounded by lines of harder enamel. These curious enamel patterns are of great importance in the classification of the animals, as they are but slightly affected by age and wear and are remarkably constant for each species.

About 165 living species and subspecies of *Microtus* have been recognized (1904), of which about 78 are North American.^a Eight extinct fossil species have been described, and several of the living forms also have been found fossil.

The genus *Microtus* is of wide distribution, covering practically the greater part of the northern hemisphere outside the tropical zone—America north of the Tropics, all of continental Europe, and Asia, except its southern peninsulas. Great Britain has two species, but Ireland and the principal Mediterranean islands have none. The genus is not found in South America, Africa, Australia, or the Australasian islands. While true mice (*Mus*) are found over a large part of the range of *Microtus*, they do not extend so far northward and occur much farther southward. *Microtus* finds its most southerly extension in the Old World in Palestine and the southern slope of the Himalaya Mountains; in America, in southern Mexico and Guatemala.

The range of a single species is often remarkably great. Thus the typical form of the common meadow mouse of the United States (*M. pennsylvanicus*) occurs over a large part of at least twenty-five States, from Maine to the Dakotas and southward almost to 35° north latitude. If the five subspecies (geographic races) are included, this range is almost doubled in extent. Another species, *M. mordax*, occurs in most of the high mountains from Colorado to California and from Arizona to Alaska. The meadow vole of Great

^a For key to the North American species and descriptions the reader may consult N. A. Fauna No. 17, Revision of American Voles of the Genus *Microtus*, by Vernon Bailey, 1900.

Britain (*M. agrestis*), common from the Orkney Islands to the English Channel, is also distributed over much of northern Europe. Another closely related species, *M. arvalis*, has a still wider distribution in central and southern Europe, and, strange to relate, is found in England as a fossil.

On the other hand, some of the species of *Microtus* are of limited range, a few of them being confined to the summit of a single mountain or isolated on a single small island. The beach vole, for instance, occurs only on Muskeget Island, Massachusetts, while the Gull Island vole (*M. nesophilus*) of Great Gull Island, in Long Island Sound, was of such limited distribution that grading and excavating for fortifications probably resulted in the total extinction of the species.

The several species differ greatly in size. Including the tail, some are even shorter than the common house mouse, while others are as large as a medium-sized rat. The largest species is the Florida water rat (*Microtus allenii*), whose total length is about 320 mm. (12.5 inches). The smallest American species is the dwarf vole (*M. pennsylvanicus*), whose total length is 115 mm. (4.5 inches). While the tail of field mice is usually very short in proportion to total length of the animal, the various species differ greatly in this particular. The males of many species give off a strong odor; much like that of the muskrat.

HABITS OF FIELD MICE.

While the food habits of the various species of short-tailed field mice are remarkably similar, their breeding and general habits differ greatly. The variety of habitats is most striking. Some species prefer high and dry ground, while others live in low, moist places. Occasionally the same species inhabits both sorts of localities. Some species live in forests, others in the open prairies. Some burrow under the ground like moles, while others make smooth paths or trails upon its surface.

Except in cold weather, nearly all species can temporarily adapt themselves to moist surroundings; but a few seem to be almost as aquatic as the nearly-allied muskrat. This is true especially of the larger species, such as the Florida round-tailed "muskrat" (*M. allenii*) and the European water vole (*M. amphibius*), both of which swim and dive with such facility that they are popularly called "water rats."

NESTS AND TRAILS.

The nests of field mice are compact bunches or globes, composed chiefly of grass blades and other dry vegetable fibers. They are placed in depressions in the ground, in shallow burrows, or supported on grass stems above the ground. In brush piles the writer has

found them nearly a foot above the ground. Sometimes they are placed under flat stones or logs or under shocks of grain. The structures are so slight that a day's sunshine will dry them out after a storm, and yet they are so compact that the animals pass the coldest weather snugly housed in them under the snow.

The nests are admirably located with respect to drainage, being so placed that they are not likely to be flooded during excessive rains, and often being in depressions of mounds made by the mice, well above the general surface of the meadows.

Trails, often of great length and worn smooth by constant use, lead to neighboring feeding grounds. As far as possible they are under shelter of old grass, fallen weeds, leaves, and other material. The trails of some species are almost entirely below the surface of the ground, and short tunnels are common with most species. At intervals burrows of varying depth occur, usually but a few inches below the surface. These lead to underground nests, to the roots of food plants, or serve only for refuge from enemies.

BREEDING HABITS.

While most surface nests are for shelter only, sometimes the young, especially of swamp species, are produced in them. However, the young of most kinds are born in underground nests and are rarely seen unless uncovered by accident. They are at first hairless and blind. When discovered in the nest the mother vole slips noiselessly away, sometimes carrying the young attached to her mammae.

The breeding season includes most months of the year, except mid-winter in cold latitudes and periods of long-continued drought. The number of litters in a year thus depends on climate, and especially upon the character and length of the winter. In temperate latitudes in normal seasons from four to six litters are produced. Even the same species in different localities differs much in this particular. That the number of young in a litter varies with the different species may be inferred from the variation in the number of teats. Some species produce normally from two to four young, others from four to eight; but the variation in the same species is remarkable, and depends partly upon climate, but probably more on the scarcity or abundance of food. The largest litter recorded by the field naturalists of the Biological Survey is thirteen, the species being the dwarf vole (*M. nanus*). The period of gestation is not positively known, but probably is about twenty days. Members of the Biological Survey have recorded finding young of the American species in the nests, or females containing embryos, in every month of the year except January and February.

European testimony proves conclusively that, like the lemmings, voles at times increase in numbers abnormally, but the causes are

little understood. So rapidly do they multiply at such times that the results are astonishing. Females become pregnant within a few days after giving birth to a litter, and the number of young at a time is abnormal. The published accounts of conditions subsequent to and during such periods are highly interesting.

Dr. A. E. Brehm, quoting Blasius and Lenz, states, concerning the field mice of Germany (*M. arvalis*), that in 1822 in the district of Zabern 1,570,000 were caught in fourteen days. During the same time in the district of Nidda 590,427 were caught, and in that of Putzbach 271,941. In the autumn of 1856 there were so many voles in one district between Erfurt and Gotha that about 12,000 acres of land had to be replowed because of the destruction of the first crop. On a single large estate near Breslau 200,000 were caught within seven weeks and sold to a Breslau fertilizer factory at a pfennig (nearly one-fourth cent) per dozen. Some of the vole catchers caught 1,400 to 1,500 per day. In the summer of 1861, in the neighborhood of Alsheim, in Rhenish Hesse, 409,523 were caught. The local authorities paid 2,593 gulden (about \$1,000) for their capture.^a

Louis Figuier, the French naturalist, writing of the same species, says that the female gives birth to from eight to twelve little ones three or four times in a year, and that multiplication is so rapid at times that "whole districts have been reduced to destitution by this scourge. In 1816 and 1817 the one department of Vendée experienced a loss estimated at £120,000 [nearly \$600,000], caused entirely by these animals."^b

The common meadow mouse of the United States is one of the most prolific of our species. Estimating the normal increase at six young, with four litters in a season, and assuming that there were no checks upon the increase, the results are appalling. A single pair and their progeny in five seasons would amount to nearly 1,000,000 individuals. This calculation is under the mark, since it is based on the assumption that the young do not breed until about a year old. The animals, however, mature very rapidly, and the spring young undoubtedly breed in the fall of the same year.

If a thousand pairs of field mice survive the winter in any neighborhood, the potential conditions for a vole plague are present. If, now, instead of normal reproduction, circumstances bring about a considerable increase both in the number of young at a time and in the number of litters in a season, the probability of a plague is greatly increased. Hence the farmer needs the good offices of every creature that preys upon mice, to supplement the climatic limitations upon their increase and to aid in saving his crops.

^a Thierleben: Säugethiere, vol. 2, pp. 387-393, 1877.

^b Mammalia Popularly Described by Typical Species, L. Figuier, p. 445, 1870.

FOOD HABITS.

Owing to its finely chewed condition, exact determination of the food of rats and mice from stomach examinations alone is very difficult. This is especially true of the species of the genus *Microtus*, whose molars are well adapted for grinding. So complete is the mastication and subsequent maceration of weed and grass seeds, as well as roots and grains, that the cell structure is often destroyed. A fair idea of the food can be gained, however, by a study of the animal's environment, by the color of the stomach contents when bark has been eaten, the odor of wild onions when present, the presence of starch grains revealed by the microscope, or the character of the few perfect vegetable cells that remain. The bits of stems, blades of grass, and leaves of other plants left scattered along the runways are important evidence, as also are the contents of the caches of food in the burrows.

In summer the principal food of these mice is green vegetation and unripe seeds of grain and grasses. As the season advances, ripe grain and seeds take the place of the immature; and in winter bulbous and other roots are in part substituted for stems and leaves. When convenient, and green vegetation is lacking, the bark of trees and shrubs becomes a staple food. It is mainly in winter that apple orchards and young forest trees suffer from attacks of mice. It is generally supposed that such attacks are due to the absence of ordinary food; but this is not always the case, for depredations often occur during mild, open winters when food abounds. Instances also of summer girdling of trees are well attested.

Examinations of stomachs of field mice show that, besides stems, leaves, and seeds of grasses and sedges, the animals eat nearly all kinds of bulbs, tubers, and roots, and occasionally animal food such as snails and crayfish. Outside the list of grains, vegetables, grasses, roots, and barks, which are generally known as staple food of field mice, they have been found eating strawberries and other fruits; roots of wild morning-glory (*Convolvulus sepium*), sweet clover (*Melilotus alba*), and cat-tails (*Typha latifolia*); seeds of iris and primrose (*Primula parryi*); bulbs of tulip, hyacinth, and wild onion; and the tubers of the Jerusalem artichoke (*Helianthus tuberosus*).

The quantity of green vegetation eaten by a single adult field mouse in the course of a year has been calculated at from 24 to 36 pounds. When one considers in connection with this estimate the great numbers of these animals in our meadows, swamps, and forests, the total quantity of food consumed by them appears so enormous as apparently to exceed the productive capacity of the soil. A thousand mice in a meadow would require at least 12 tons of grass or other green vegetation to maintain them for a year.

That a thousand of these small animals often inhabit a single meadow is not an extravagant estimate. Indeed, that number is often exceeded. Careful estimates made in France during 1893 placed the number in one district (Bar-sur-Seine) at 10,000 per hectare (about 4,000 per acre). In 1904, in the Department of Charente, the average number per hectare (2.47 acres) was estimated at 1,350 (540 per acre). Fortunately, conditions in America appear to be less favorable to their increase, and the natural enemies of mice have not yet been exterminated to such an extent that they fail to check the excessive multiplication of the rodents.

STORING FOOD.

European naturalists nearly all agree in stating that field mice store food for winter use and that the animals hibernate during cold weather. Brehm says that the common species in Germany (*Microtus arvalis*) collects fallen haws, juniper berries, beech mast, acorns, and nuts into its burrows. During the coldest weather they fall into uninterrupted hibernation, but when mild weather returns they rouse up and feed on their stores.^a Similar statements are made of other species and confirmed by other writers.

The most noted example of provident preparation for winter is afforded by the economic vole (*M. œconomus*) of eastern Siberia, whose migrations have already been described. These animals are said to lay up large stores of food during summer—20 and even 30 pounds of fresh roots have been found in one hoard.^b The Kamchatkans habitually rob these stores of food for their own use—a fact which accounts for the favor with which they look upon the animal.

American voles, so far as known, do not hibernate, but are active in winter even in the far north. So thoroughly has this fact been proved by observation that it seems possible that European observers may be mistaken as to the hibernation of Old World species. The habit of storing food seems to be less common in this country than with Old World species, but it is far from rare. Caches of food are often found, which show that in times of abundance the animals store away more than is needed for immediate use.

One American species, the tundra vole (*M. operarius*), exhibits in its provident habits a resemblance to the economic vole. The animal is small, inhabiting mossy tundras of western Alaska, from Cape Vancouver north to Bering Strait and up the Yukon Valley to the boundary of the British possessions. According to E. W. Nelson, it gathers stores of small bulbous roots, sometimes placing a peck or more in a single cavity just below the surface on a mossy knoll or

^a Thierleben: Säugethiere, A. E. Brehm, vol. 2, p. 388, 1877.

^b History of Quadrupeds, by Thomas Pennant, vol. 2, p. 194, 1793.

slope. In autumn, shortly before the first snowfall, the Eskimo women and children discover these stores by means of pointed sticks. In this way considerable quantities of food are gathered, which are boiled and eaten as a delicacy. "The boiled roots have a flavor like a boiled unripe sweet potato, and are very palatable during the long winter fare of meat and fish."^a

THREE TYPICAL SPECIES.

I. THE COMMON MEADOW MOUSE.

Microtus pennsylvanicus (Ord.) (Pl. I, fig. 1).

The most familiar of American species of *Microtus* is the common meadow mouse (*M. pennsylvanicus*). The average measurements of adults are about as follows: Total length, 170 mm. (6.6 inches); tail vertebræ, 46 mm. (1.8 inches); hind foot, 21.2 mm. (0.83 inch). The tail is always at least twice as long as the hind foot. The fur is long and overlain with coarse black hairs. In summer the ears overtop the fur. In winter the fur is longer, of a duller color, and almost conceals the ears. The usual color above is a dark brown, against which the black hairs are not conspicuous. This shades off gradually into gray or tawny on the under parts. The feet are small, the claws on the hind feet slightly larger than those on the front. The foot pads are 6; the mammae 8 (4 pectoral and 4 inguinal).^b

The vast range of this species has already been given. This mouse has its natural habitat in moist meadows and grassy borders of swamps, but it habitually extends its range into neighboring cultivated fields, waste lands, and open spaces on the border of timber lands. Wherever it occurs, it is normally the most abundant rodent. Nearly all meadows are full of the animals. On parting the thick grass almost anywhere one can find the smooth trails, and where the grass is thin they are often plainly visible. After the melting of deep snow, or where the dry grass has been burned, the network of runways is especially conspicuous to the eye. In swamps the paths cross soft mud and standing water, if shallow. When green scum, composed of minute floating plants, covers stagnant water, the trails are defined across it by streaks of clear water where the animals swim from side to side in the pools. In walking across a swamp one sometimes frightens them from the shelter of tussocks and sees them swim away or run through shallow water.

In swamps meadow mice nest in burrows in dry tussocks or in bunches of grass above the surface of the moist ground. The nests are composed of grass or fibers of weeds made into balls, loose and of

^a Proc. Wash. Biol. Soc., vol. 8, pp. 139-142, 1895.

^b For dental and skull characters consult N. A. Fauna No. 17, p. 17, 1900.

coarser materials outside, but compact and of finer stuff within, each having a small opening on the side near the bottom. From this opening two or more trails diverge, one usually leading into an underground tunnel which opens at some distance from the nest. Nests intended to receive the young are lined with the softest of accessible materials, often with pappus of milkweed (*Asclepias*) or cat-tails (*Typha*). Such nests are sometimes hidden under grass, brush, or other litter, but more frequently are placed in underground burrows. The normal number of young varies from four to eight, the average being about six.

The trails of meadow mice are interesting subjects for study. The animals take advantage of all sorts of shelter, especially that which is close to the ground. Under fallen leaves and weeds the trails become half tunnels. Even in the open meadow they are often entirely hidden under old grass, and their presence would hardly be

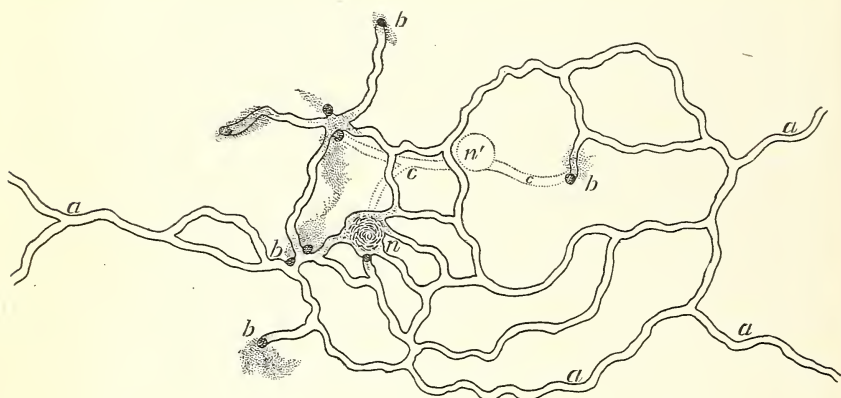


FIG. 1.—Nests, burrows, and trails of *Microtus pennsylvanicus*. *a*, Surface trails; *b*, opening to burrows; *c*, underground tunnels; *n*, surface nest; *n'*, underground nest.

suspected from any surface indications. Under the favoring shelter of piles of weeds, grass, or other litter the trails made by the animals are usually more intricate than elsewhere. The accompanying sketch (fig. 1) was made from trails and nests uncovered by removing a pile of weeds.

The rapidity with which meadow mice work is surprising. If the nest is destroyed they choose a new site and construct a new nest of fresh materials in a single night. They work both night and day, but are especially active in the evening and early morning. They are less active in the middle of the day, especially in sunlight.

When disturbed in their homes meadow mice rush about with great celerity; but in sunlight especially they do not see well, and are almost as liable to rush blindly toward the point of danger as away from it. When cornered, they stand on their haunches and defend themselves

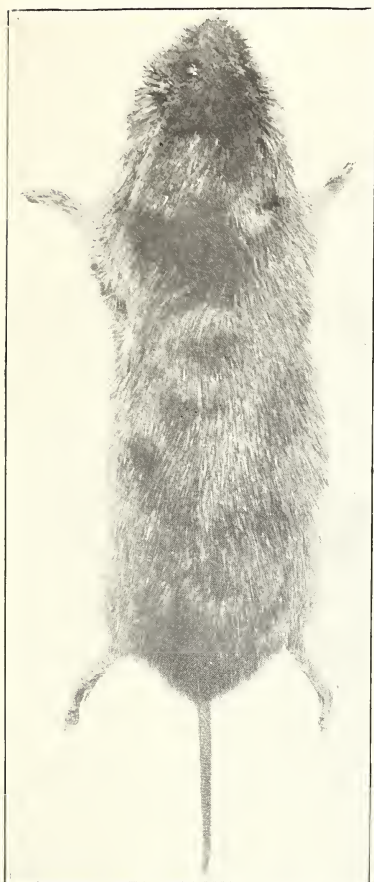
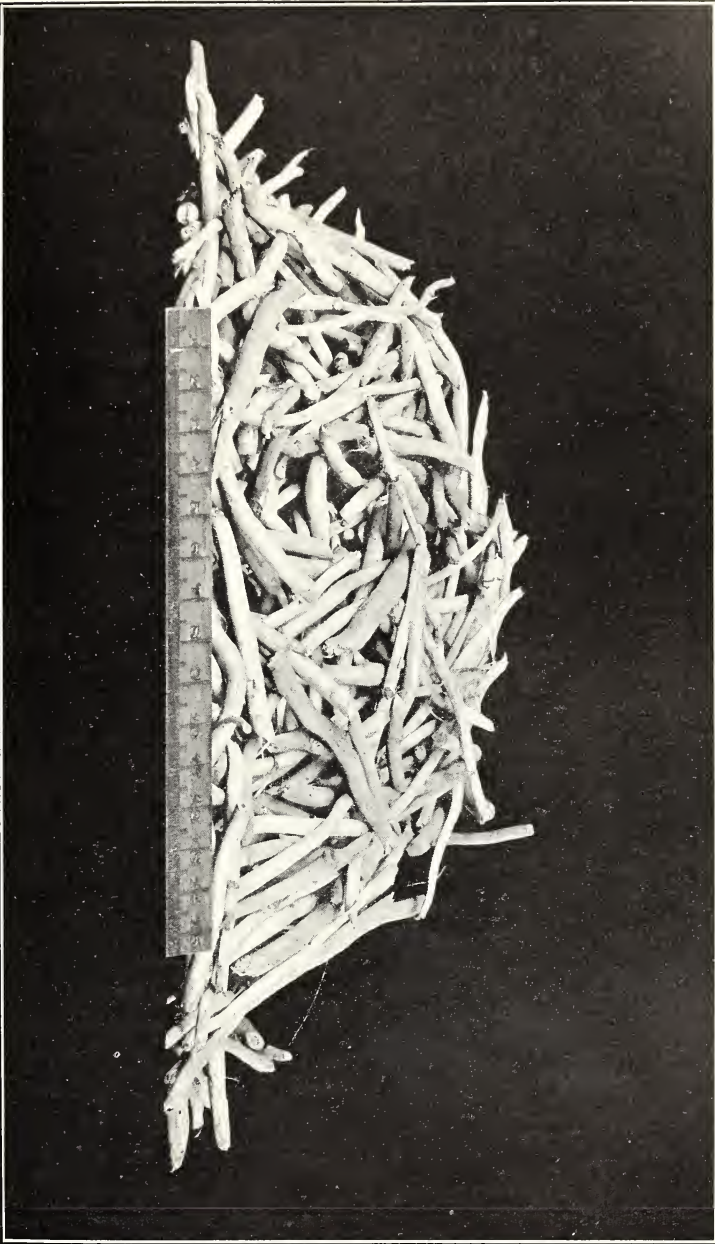


FIG. 1.—MEADOW MOUSE (*MICROTUS PENNSYLVANICUS*).



FIG. 2.—PINE MOUSE (*MICROTUS PINETORUM SCALOPSOIDES*).





ROOTS OF WILD MORNING-GLORY (*CONVOLVULUS SEPIUM*) STORED UNDERGROUND BY A PAIR OF MEADOW MICE (*MICROTUS PENNSYLVANICUS*).
[Weight of roots, 18 ounces. The scale in the illustration is 6 inches long.]



with great valor, and their sharp teeth are rather formidable weapons. Sometimes after capture one seems to give way to uncontrollable anger, and when placed in a cage with others of the same species it is eager to attack all its fellows. When two engage in combat they stand up on the hind feet and fight with claws and teeth, keeping up a constant squeaking.

Meadow mice soon adapt themselves to confinement. They eat almost any food offered and soon become tame. I find, however, that certain succulent roots, particularly those of the wild white morning-glory (*Convolvulus sepium*), are preferred to everything else. This root tastes much like sweet potato and is abundant in swamps and waste places frequented by the mice. While feeding they sit up on their hind legs and use the front paws to handle the roots, after the manner of squirrels.

This species often stores up food in underground galleries. I have several times discovered such hoards, consisting of leaves or succulent stems, but more frequently entirely of the morning-glory roots already spoken of. On March 5, 1907, I collected the contents of such a cache, which weighed 18 ounces (Pl. II).

The species under consideration never lives in barns or outbuildings. Its nearest approach to human habitations is the stackyard or piles of wood or boards left on the edge of orchards or fields near houses. In the far north a closely related species, the Drummond vole (*M. drummondi*), enters houses and barns much after the manner of the common house mouse.

The common meadow mouse is especially noted for long winter excursions from its summer abode, hiding its movements under cover of deep snow. The journeys of the animals are not suspected until the snow disappears, when the trails can be traced to great distances. They reach wheat, rye, clover, and timothy fields and often extend into orchards, nurseries, lawns, and gardens, all of which are injured by the animals. Haystacks or shocks of corn and other grain are sure to suffer if left out over winter.

The Old World species of field mice most noted for extensive ravages of crops, and including such well-known forms as *M. agrestis*, *M. arvalis*, and *M. hartingi*, are very closely related to our common meadow mouse. Many of the more prominent American species, as the Drummond vole (*M. drummondi*), the Peale vole (*M. montanus*), the dwarf vole (*M. nanus*), the Townsend vole (*M. townsendi*), and the California vole (*M. californicus*), belong to the same group. Their wide distribution brings meadow mice into contact with agriculture over great areas, and this fact, added to their prolific breeding, renders the group the most destructive one in the genus under consideration. As farming is pushed northward in the British

provinces and as the cultivated areas in the West are extended under the stimulus of the United States Reclamation Service, the danger of serious ravages by meadow mice will increase rather than diminish.

II. THE PRAIRIE MOUSE.

Microtus ochrogaster Wagner.

The prairie mouse is probably second only to the common meadow mouse in the extent of its injury to crops. Outwardly it differs but slightly from the latter species. Its tail is shorter (less than twice the length of the hind foot) and its fur is coarser. In winter the pelage is grayer. The color of the underparts shades into a buff or cinnamon. The contrast between the upper and lower parts of the tail is much sharper than in the common meadow mouse. The foot pads are 5, and the number of mammae 6 (2 pectoral and 4 inguinal). Its average measurements are about as follows: Length, 155 mm. (6 inches); tail vertebrae, 38 mm. (1.5 inches); hind foot, 21 mm. (0.82 inch).

The prairie mouse occurs in southern Wisconsin, in Indiana, Illinois, Iowa, Missouri, Nebraska, Kansas, and a part of Oklahoma. It lives in the open prairie country, mainly in the Upper Austral zone. Thus it is much more likely to invade crops than if its natural habitat were in swamps. I have found it on the borders of corn and cane fields and in native meadows, as well as in cultivated clover and alfalfa fields. It seems especially partial to fields that have been allowed to lie fallow for several seasons. The soft mixed annual grasses and weeds that partly replace the original prairie cover seem to furnish it congenial surroundings. Close grazing of the open ranges tends to drive out voles, but when ranges are not closely pastured, so that an abundance of old grass is left, prairie mice soon become numerous and appreciably reduce the amount of forage.

In the same manner the prairie mouse invades pastures and neglected orchards whenever dry grass is permitted to accumulate and remain over winter. If no crops are near, the animals subsist on wild herbage, roots, and seeds; but when cultivated crops are accessible their trails soon extend far into the tilled fields.

Nests of prairie mice usually are less bulky than those of the common meadow mouse, but are built in a similar way and in like situations. The number of young at a birth is usually three or four, rarely five or six. In ordinary seasons the first litter is born in April, but in dry, warm springs the time may be fully a month earlier. The number of litters in a season varies with climatic and other conditions. On the whole, prairie mice multiply less rapidly than meadow mice, since the number of young at a birth is smaller, and the long summer droughts and extreme winters of the interior prairies of the West often limit reproduction.

Robert Kennicott's excellent account of this species^a states that in confinement the animals were practically omnivorous, rejecting but little vegetable food offered them. The amount of food consumed was astonishingly great. Three ate in twenty-four hours, besides other food, the germs from all the kernels of a large ear of corn. They ate raw fresh meat and drank much water.

My own observations of the prairie mouse confirm published accounts. Near alfalfa fields in Kansas I found that the green leaves of this forage plant were the favorite food. This was made evident by the trails leading to the fields and by careful stomach examinations of individuals captured.

In winter the prairie vole sometimes does enormous damage to fruit trees. In this respect it is, if possible, more destructive than the common meadow mouse; and as the fruit industry in the West grows in magnitude this species is likely to become still more troublesome. In Kansas and Missouri, during the winter of 1903-4, many orchards and nurseries were severely injured by the prairie mouse, and during the two following winters the losses were greater rather than less.

This species comes into contact with agriculture in the major portion of eight States lying in the humid section of the central Mississippi Valley. These eight States produce annually more than half the corn, oats, and winter wheat, and more than a third of the hay of the entire United States. Two closely related species of prairie mice (*M. haydeni* and *M. minor*) extend the range of this group on the plains to the west and northwest. Here they are abundant in sections where barley and spring wheat are important crops. The possibility of serious crop damages from prairie voles is, therefore, especially great.

III. THE PINE MOUSE.

Microtus pinetorum scalopsoides (Aud. & Bach.). (Plate I, fig. 2.)

This pine mouse, called also the mole-like vole, has a wider distribution than the typical southern pine mouse (*M. pinetorum*), and therefore is chosen as the representative of the group. The following account of its habits applies equally well to all pine mice.

This animal has the wide, flat skull, the short tail, the small ears, and the short, dense, glossy brown fur characteristic of all the pine mice. The colors, however, are less glossy and the size somewhat larger than in typical *M. pinetorum*. The claws are well developed; foot pads 5; mammae 4 (2 pairs of inguinal). The average measurements of three New York specimens, as given by Bailey, are as fol-

^a The Quadrupeds of Illinois Injurious and Beneficial to the Farmer. Patent Office Report: Agriculture, 1856, pp. 97-102, 1857.

lows: Total length, 125 mm. (about 5 inches): tail vertebræ, 20 mm. (0.78 inch); hind feet, 16.3 mm. (0.64 inch).^a

Owing to their peculiar habits, pine mice are not so well known as are meadow mice. Their natural habitat is the forest, although they are by no means restricted to pine woods or forested areas. While often inhabiting pine woods and the edges of adjacent fields, they live also in forests and copses of deciduous trees, usually on uplands.

The life of pine mice is largely spent in underground tunnels, which so closely resemble those of the mole that generally they are mistaken for the work of that animal. The ridges of loose soil over the tunnel are exactly like those thrown up by the mole, but the inner diameter of mouse tunnels is less. When moles and pine mice live in the same vicinity, the mice often use the runways made by the moles. It is this habit that has helped to bring moles into disrepute with farmers, who blame them for damages inflicted upon potatoes and other crops by pine mice.

In marked contrast with the pine mouse, the mole (genus *Scalopus*) is almost exclusively carnivorous, eating mainly earthworms and insects. While it sometimes cuts off the roots of growing plants when they interfere with its tunneling operations, it apparently eats no roots. Stomach examinations of moles show that they eat a very small percentage of vegetable matter, and this mainly waste corn or other grain previously softened by long contact with wet soil. On the other hand, pine mice eat little insect food, if any, and are largely consumers of vegetable substances. Nearly always when moles are charged with destroying root crops, the real culprits are pine mice.

Thin, open woodlands used for pasture, and thickets along the edges of forests are favorite resorts of pine mice. Like nearly all voles, they prefer moist soil, but it must also be loose and somewhat sandy. From their intricate tunnels under the leaf mold frequent burrows descend into the soil. Some of these burrows are utilized as nesting places. Nests are built also at the surface of the ground, under fallen logs, brush heaps, flat stones, fences, or other shelter.

The number of young at a birth evidently averages less than is usual in the genus *Microtus*, as is shown by the small number of mammae. Observations as to the number of litters in a season seem to be lacking, but the rate of reproduction is probably less in the pine mice than in any other American group of field mice. Blasius says concerning *M. subterraneus* of Europe, that "it produces five or six times a year three to five young, which are blind for ten days after birth;"^b and this statement is probably true, with slight modification, for all the species of the group. To compensate for slower multiplication, their liability to attack by natural enemies is much

^a N. A. Fauna No. 17, p. 64, 1900.

^b Naturgeschichte der Säugethiere Deutschlands, p. 390, 1857.

less, owing to their underground existence; so that within their range pine mice are about as abundant as other field mice.

Quick and Butler, writing of the food habits of the pine mouse in Indiana, state that it lives upon the tender roots of young hickories, the young sprouts of white clover, the fruit of the red haw, and the tuberous roots of the wild violet (*Viola cucullata*). The writers found all but the fruit buried, some in deposits of a gallon in a burrow, and the caches sometimes extending 18 inches below the surface of the ground. Violet roots predominated in these stores.^a Kennicott also states that pine mice store acorns and nuts in burrows for winter use. Blasius and Brehm both state that the European species (*M. subterraneus*) prepares such stores. While personally I have never found such deposits, it is probable that our species have this habit to an extent greater than is generally known.

From their homes in woods and thickets pine mice invade fields, orchards, nurseries, dooryards, and gardens, passing always through underground runways. Living in concealment, neither their presence nor the injury they inflict is suspected until the latter is past remedy. Bulbs, planted hopefully in autumn, appear not at all in spring, or only in the shape of sickly plants whose life substance has been gnawed away. Nursery and orchard trees here and there put forth no leaves, and an examination of the roots discloses the nature of the damage.

Potatoes, sweet potatoes, carrots, beets, and other vegetables are eaten by pine mice, both while growing and when stored in pits or lying in piles in the field or garden. Potatoes partly matured or left long in the ground after maturity are eaten, and the injury is attributed to moles, because tunnels supposed to be the work of moles lead to the place of damage. I have investigated numerous cases of such injury and have invariably found either that the tunnels were made by pine mice, or, if mole tunnels, that they were frequented by mice. Traps set in the tunnels at the potato hills captured pine mice, and the starchy material found in the stomachs of those caught proved that they, and not moles, had been eating the potatoes.

Pine mice occur in central and southern Europe, in the eastern United States, and in a limited part of eastern Mexico. Those in the United States occur chiefly in the Upper Austral zone. The typical species (*M. pinetorum*), with bright russet-brown color and glossy mole-like fur, is found only in parts of Georgia, South Carolina, and southern North Carolina. In the last-named State it grades into the subspecies *scalopsoides*, which is much more widely distributed, ranging northward to southern New York (Hudson Valley and Long Island) and westward to Illinois. West of the Allegheny Mountains it occurs mainly north of the Ohio River, except in West Virginia.

^a American Naturalist, vol. 19, p. 116, 1885.

The bluegrass vole (*M. p. auricularis*), a form with ears overtopping the fur, which is dark and glossy, occurs in southern Indiana and in Kentucky, Tennessee, Mississippi, and Alabama. It has been taken in northeast Texas also, so that its range probably extends through southern Arkansas and connects the two areas.

The woodland vole (*M. p. nemoralis*) is the largest form of the pine vole in America, and has longer and less glossy fur than the forms east of the Mississippi. Its color is deep chestnut, darker than typical *pinetorum*, but lighter than *scalopsoides* or *auricularis*. It occurs in wooded parts of southern Iowa, eastern Nebraska and Kansas, and in Missouri, northern Oklahoma, and Indian Territory.

Pine mice differ greatly in habits from the other species of *Microtus*. All the American representatives of the group have similar habits, and the injury they do to crops is little less in extent than that inflicted by meadow mice and prairie mice.

DAMAGE BY FIELD MICE.

While field mice of the various groups differ but little in the nature of their food, the circumstances under which they injure crops vary. Meadow mice invade cleanly cultivated fields only under the shelter of snow. Hence they do most damage in years of great snowfall. Although prairie mice commit greater depredations under cover of snow than in open seasons, their attacks upon crops are far less dependent upon snowfall than those of meadow mice. Pine mice work in the shelter of their own burrows; hence their injuries to plants are quite independent of the amount of snow.

DAMAGE TO MEADOWS AND PASTURES.

Complaints of damage to meadows and pastures by field mice have been increasing in recent years. Usually the injury is confined to small areas, which the animals attack from the shelter of snowdrifts or old grass. Under cover of these, the animals eat the succulent crowns of clover and other grasses; and when the snow lies for several weeks the crops over large areas are often completely ruined. Sometimes whole fields of red clover are so badly damaged by mice that they have to be replowed in the spring and planted to other crops.

Damage to permanent, or uncultivated, meadows is usually more serious, as the mice breed and multiply throughout the field and, under cover of the growing crop of leafy stubble, devour and destroy throughout the year. Occasionally, however, actual benefit may result from their thinning the grasses and stirring the soil about the roots. Thus, after the vole plague in Scotland in 1892, the farmers reported that the pastures were better than before; but the improvement by no means compensated for the losses caused by the impaired pasturage of the two preceding years.

When mice are abundant during the growing season, the quantity of grass they destroy is great, more being cut down and left upon the ground than is actually consumed. In winter hay in stacks is injured by field mice, and instances are known in which large stacks were so badly damaged that in the spring little or no salable hay remained.

DAMAGE TO GRAINS AND FORAGE.

Growing grains—wheat, oats, barley, rye, and buckwheat—are destroyed by field mice. Attacks begin with the sprouting grain, and, in the case of fall sown wheat and rye, continue during the entire winter. However, when only the blades of the plants are eaten this winter consumption has but little effect upon the amount of grain subsequently harvested. Much greater damage is done when the grain is nearly mature, as stalks are then cut down. After the grain ripens, devastation by mice continues until after harvest, when the animals attack the shocked grain and even the stacks. The total amount of injury by mice depends both on the number of the animals present and on the length of time the grain is left in shocks. In these artificial shelters mice are perfectly at home and multiply with great rapidity, so that within a few weeks a pair and their progeny may totally ruin an entire shock of wheat or oats.

As nearly all farmers know, field mice destroy corn, Kafir corn, and cane, whether stored in shock or in pile. The annual destruction both of grain and of forage throughout the country is enormous, although accurate statistics of losses are not available. Of course, not all the injury is done by short-tailed field mice. White-footed mice (*Peromyscus*), pocket mice (*Perognathus*), harvest mice (*Reithrodontomys*), and ordinary house mice (*Mus musculus*) also are concerned in the damage. Throughout the country the brown rat (*Mus norvegicus*) and in the Southwest the cotton rat (*Sigmodon*) are serious field pests. The several kinds of field mice, however, partly because of their wide distribution, but mainly because of their great abundance, are the chief offenders in northern fields.

Grain and forage in stacks are often injured by field mice. In view of the losses to which stacked and stored grain is subject, it is a question whether the farmer who hastens to market his crop is not, on the whole, a gainer over his neighbor who waits for more favorable prices.

DAMAGE TO GARDEN CROPS.

Field mice do much injury in market and other gardens, attacking planted seeds in the open garden, hotbed, or cold frame. Pine mice are the chief offenders in inclosures, sometimes working their way even into greenhouses, where they attack bulbs and tender growing plants, as well as all kinds of seeds.

Field mice injure early peas and other vegetables growing in open grounds, and pine mice often destroy potatoes in the ground. In the fall vegetables piled on the ground or stored in pits are liable to attacks. Among these are potatoes, beets, turnips, carrots, parsnips, cabbage, sweet potatoes, and especially celery. Apples, pears, and other fruits are eaten also.

In parts of eastern Maryland pine mice have recently (1907) been quite destructive to melon and cantaloupe crops. The animals destroy the seed and eat the roots of the plants during the growing season. The injury was greatest on sandy lands which had not been plowed before planting, but had been smoothed with a drag, leaving the mouse tunnels below undisturbed. In some fields seed had been planted three times, but by the middle of July all hope of a crop had been abandoned.

DAMAGE TO SMALL FRUITS.

Blackberries, raspberries, grapes, currants, gooseberries, and strawberries are often badly damaged by field mice, and when the animals are abundant whole plantations are ruined. Strawberries are especially liable to injury because of winter mulching and also because the plants themselves furnish excellent food and shelter for the animals.

Fallen leaves in autumn and snow in winter drift and collect along rows of blackberry, raspberry, gooseberry, and currant bushes and furnish cover for mice, which work along the rows and girdle the green stems; and when dead canes are left uncut and weeds are permitted to grow up among them, the resulting tangle adds much to the liability of attack. Winter mulching of small fruits also increases the danger, and if practiced the utmost care should be taken to clean surrounding areas.

DAMAGE TO NURSERY STOCK.

In many sections of the United States and southern Canada nursery stock is injured by field mice. The actual loss varies from year to year and is difficult to estimate. Occasionally the havoc has been so complete that few marketable trees remained. It was estimated that during the winter of 1901-2, nurserymen in the vicinity of Rochester, N. Y., sustained losses amounting to \$100,000.^a

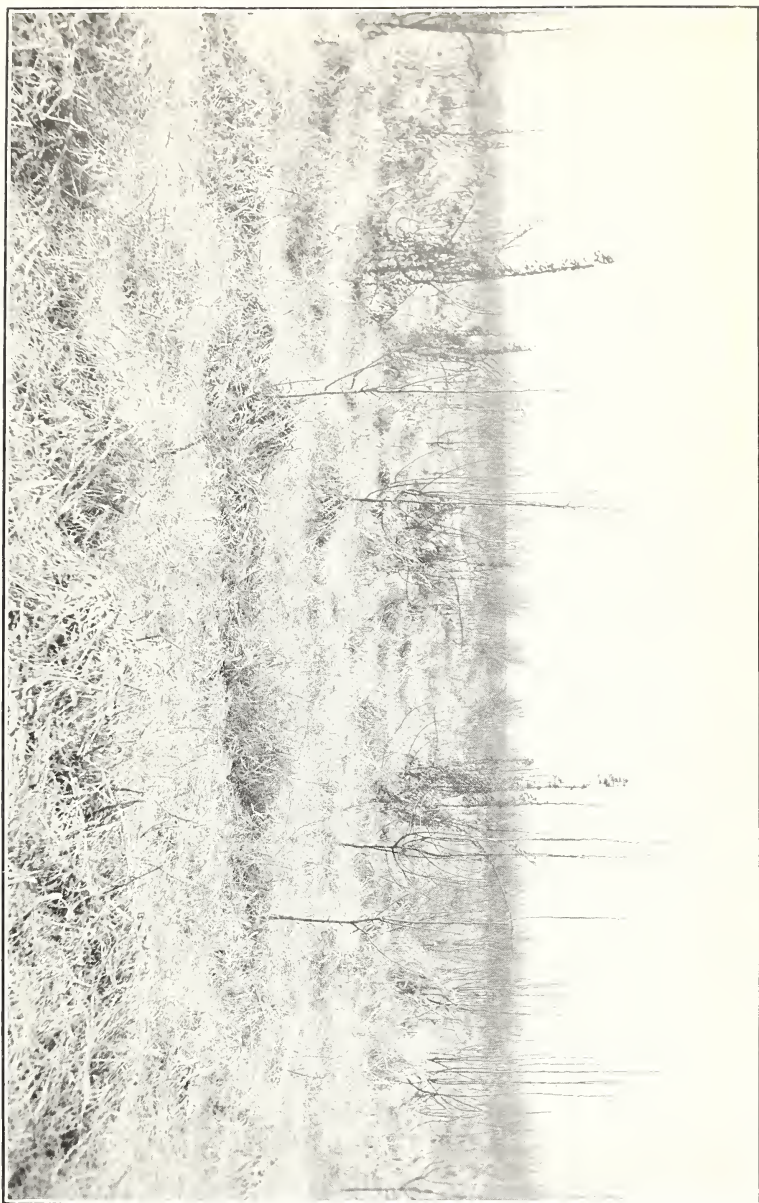
Damage to standing nursery stock is done usually under cover of snow, and hence is greatest in seasons of deep snows that remain long upon the ground. In addition to girdling trees above the surface of the ground, meadow mice sometimes burrow beside the trunk and attack the roots (Pl. III, fig. 2). Pine mice usually begin their

^a New York Sun, April 27, 1902.



FIG. 1.—YOUNG APPLE TREE EATEN BY PINE MICE. FIG. 2.—YOUNG APPLE TREE EATEN BY MEADOW MICE.





A NEGLECTED YOUNG ORCHARD IN WINTER, WHERE MEADOW MICE RUN RIOT.





FIG. 1.—PEAR TREE INJURED BY MEADOW MICE.



FIG. 2.—APPLE TREE INJURED BY MEADOW MICE.

attacks below the surface and except under cover of snow rarely extend them above ground. They sometimes consume the entire roots of small apple trees so that only the trunk is left (Pl. III, fig. 1). Experienced nurserymen prevent serious injury to standing stock by clean cultivation. Stock that has been taken up in the fall and "heeled in" or kept in storage pits is, however, liable to attack, especially if covered by straw, leaves, or other litter. Hence for protection from freezing a loose covering of soil is better than litter. Winter seed beds of conifers, oaks, and nut-bearing trees are often attacked by field mice and need to be carefully protected from them as well as from white-footed mice (*Peromyscus*). Small pine trees in the nursery also are liable to injury, since their low branches usually furnish cover for mice.

Among the nursery stock injured by field mice are apple, pear, quince, plum, peach, cherry, crabapple, sugar and Norway maple, chestnut, black locust, Osage orange, sassafras, alder, white ash, mountain ash, various oaks, cottonwood, willow, pine, and wild cherry trees; also blackberry, raspberry, rose, currant, and barberry bushes, as well as grape vines. In the Arnold Arboretum, Jamaica Plain, Mass., during the winter of 1903-4, meadow mice destroyed thousands of trees and shrubs, including apple, maple, sumac, barberry, buckthorn, dwarf cherry, snowball, bush honeysuckle, juniper, blueberry, dogwood, beech, and larch. Plants in nursery beds and acorns and cuttings in boxes especially were harmed.^a

INJURY TO ORCHARDS.

Trees transplanted from the nursery into the orchard are in more danger from field mice while the outer bark is green and tender, but there are instances in which trees 5 and 6 inches in diameter have been attacked and killed by them. Most farmers are inexperienced as orchardists, and plant fruit trees only for family use. Engrossed in the production of other crops, they often neglect the orchard and permit annual grasses or weeds to grow up, which afford cover for mice. Often, too, clover or orchard grass is sown in the orchard as a covering for the ground, and the heavy growth left for winter mulch is augmented by fallen leaves. Under such conditions it is not strange that mice injure the trees. It is remarkable, indeed, that so many orchards escape injury. That they do so may in part be attributed to the fact that they are often near dwellings, where hens scratch and cats prowl.

Attacks upon orchards by mice are not always accomplished under cover of snow, nor are they confined to winter. They frequently occur in summer, often in September. During the winter of 1905-6

^a Boston Transcript, April 16, 1904.

a small orchard of apple and pear trees near Washington, D. C., was under observation from October to April. Attacks by meadow mice began in the early fall, possibly in August. They were continued during every succeeding month, being greatest during two short periods of snow. Independent of snowfall, they were greatest in mild and least in cold weather. A few trees had no weeds or grass near the trunks, and these escaped injury. The neglected condition of this orchard appears from a photograph (Pl. IV) taken January 24, 1906. Adjoining the orchard was a tangled thicket on low, moist ground, in which meadow mice were abundant.

On March 16, 1906, I found that of 380 apple trees, 164, or over 43 percent, were ruined, being completely girdled, some to a height of 8 to 10 inches above the ground. Thirty-six others, nearly 10 percent, were less badly injured, while 180, or 47 percent, apparently, were uninjured.^a

Of 200 pear trees in the orchard 50 were more or less seriously damaged. The injury to these was inflicted early in the fall.

The nature of the damage to individual trees in the orchard is well shown in Plate V.

INJURY TO FOREST TREES.

As an example of the danger from field mice to which plantations of forest trees are exposed, the following is cited: In 1813 and 1814 young plantations of trees in Dean and New forests, England, were greatly damaged by mice, probably *M. agrestis*. The damage was to planted acorns, two-thirds of which were destroyed, and to holly, oak, and chestnut trees, some of which were 5 years old. Not only were the trees girdled above the surface of the ground, but often the roots also were gnawed through. The land was covered with long grass, ferns, etc., which furnished abundant shelter for voles.^b During the winter of 1813-14 more than 30,000 mice by actual count were destroyed in Dean Forest and 11,500 in New Forest. It was calculated that the total killed by all the agencies employed was probably double these numbers. The total number of voles killed in both forests during the outbreak was estimated at 200,000.^c

In the past, American forestry has concerned itself chiefly with efforts at conservation, but forest extension has progressed far

^a On June 22, 1907, the number of apple trees alive in this orchard was 226. The dead trees numbered 154, many of which had succumbed to their injuries during the spring of 1907. The trees were thoroughly sprayed with lime-and-sulphur wash in November, 1906, and although many meadow mice and some rabbits were present, none of the trees were attacked during the succeeding winter.

^b Lord Glenbervie's Account, Zool. Journ., vol. I, pp. 433-444, January, 1825.

^c Bell's History of British Quadrupeds, p. 325, 1874.

enough to enable us to judge of the extent of injury that field mice are likely to inflict upon new plantations. The experience in the Arnold Arboretum, already referred to, is probably an example of what may be expected.

Dr. C. A. Schenck, forester of the Vanderbilt estate, Biltmore, N. C., in a recent communication to the Biological Survey, states that plantations of locust and black cherry suffer badly from the girdling of mice, "especially the locust, which are killed outright, usually the best specimens." And he adds, "Plantations of acorns, chestnuts, and hickory nuts are rendered impossible because of ravages of mice."

In our native forests the injury to young trees by mice has usually been unnoticed or disregarded; but hereafter, as more attention is given to forest extension, a corresponding increase in interest in mice as enemies of forest trees may be expected.

DAMAGE TO PARKS AND LAWNS.

Field mice destroy bulbs, perennial herbaceous plants, woody shrubs, and ornamental vines. To name all the kinds subject to attack is unnecessary, as but few are immune. The animals invade botanic gardens and public parks as well as private grounds. In the public parks of Hartford, Conn., during the winters of 1904 and 1905 much damage was done, especially to common laurel (*Kalmia latifolia*) and various thorns (*Crataegus*). Rosebushes and the crowns of hollyhocks are often attacked. Pine mice usually are responsible for the injury to bulbs—tulips, hyacinths, crocuses, etc. Often the straw or other litter used to protect tender plants furnishes shelter for the animals. Hedges, while often subject to injury from voles, also afford protection under which the animals gain access to ornamental plantations.

During the winter of 1904-5 pine mice invaded dooryards near Lanham, Md., and destroyed many plants. In one case 50 choice hyacinths and tulip bulbs in a bed were badly eaten, so that only 4 or 5 sickly plants came up in spring. In an adjoining dooryard, in the spring of 1907, the animals girdled a considerable number of young white pines (*Pinus strobus*) and ate the roots.

STUDIES IN AN ORCHARD.

In December, 1903, I examined a large orchard in Marion County, Kans., where field mice were causing much damage. As the case of this orchard is in many respects typical, details of its treatment will be given. The orchard comprised 480 acres and contained about 26,000 trees, mostly apple, eight to ten years transplanted. The trees averaged about 4 inches in diameter, but many measured 5 or 6

inches. The majority were headed low, their outer drooping branches touching the ground (Pl. VI, fig. 1). In the spring of 1903 corn had been planted by listing it in the open spaces between the rows of trees; but owing to an unusually wet summer, the crop had been abandoned, and sunflowers and other weeds and grasses had made a luxuriant growth throughout the orchard. Over much of the area, apparently, no attempt had been made to cut down the weeds; and where they had been mowed they had been raked into piles and not burned or removed.

In this neglected orchard field mice—the prairie vole—had found a congenial home. Already abundant in 1902, they bred plentifully in the open fall of that year and in the early warm spring of 1903. The ensuing moist summer also was favorable for continued reproduction, and by the fall of 1903 they were present in hordes. All the orchards of the neighborhood—a comparatively level upland prairie—had been neglected and all were invaded by mice; but the one above mentioned was the largest and most neglected, and therefore it suffered most severely. By December 18, the date of my first visit, mice had wholly or partially girdled at the surface of the ground fully 5,000 apple trees and had denuded of bark many of the low branches. The owners of the orchard, thinking that none of the trees could survive the injuries, then estimated their loss at from \$25,000 to \$30,000.

Examination showed that the ground everywhere was honeycombed by mouse burrows and tunnels to a depth of 3 or 4 inches, and that the surface was almost covered by a network of runways of the prairie vole. Upon digging into the burrows at the base of apple trees I found many twigs, 4 to 6 inches long, that had been entirely stripped of bark and left lying in little piles. I had no difficulty in finding where the twigs had been severed from low-growing branches and the tips of sprouts, and in distinguishing, by the smaller tooth marks, the cutting done by mice from that done by rabbits. Whether the twigs had been first stored and afterwards fed upon in cold weather I was unable to determine, for I found none with bark remaining upon them. Probably they were carried to the burrows merely for leisurely but immediate consumption.

Contrary to the usual habits of voles in our Northern States, this injury had been done during mild weather. Up to December 18 the season had been warm and open. No snow lay on the ground for more than twenty-four hours. Ordinary food, such as grass, seeds, and grain, was abundant, so that the only explanation for the injury to trees seems to be the vast numbers of voles present and their preference for a partial diet of bark.

Voles, however, were not the only animals abundant in the orchard. Rabbits, both cottontails and jacks, were there in great numbers, and



FIG. 1.—LOW-HEADED APPLE TREE IN A KANSAS ORCHARD.



FIG. 2.—APPLE TREE RECOVERED AFTER INJURY BY MICE.





FIG. 1.—APPLE TREE KILLED BY PRAIRIE MICE.



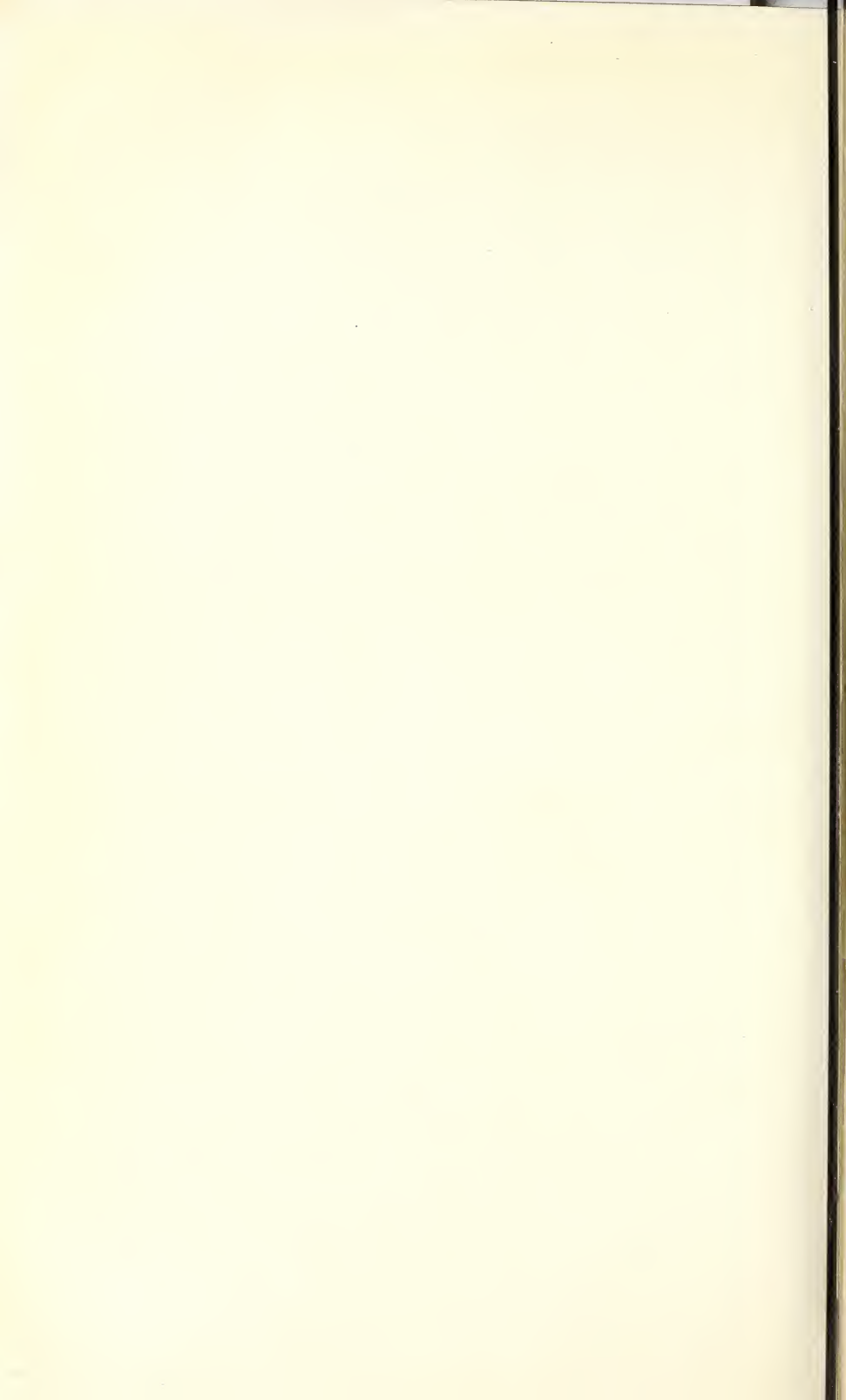
FIG. 2.—APPLE TREE KILLED BY RABBITS.





APPLE TREES 5 INCHES IN DIAMETER, GIRDED BY PRAIRIE MICE (*MICROTUS OCHROGASTER*).

[Trees saved by heaping up soil about the trunks to cover the injury.]



already had begun to eat the bark on the trunks of some of the trees and on the low limbs, and to cut the tips of branches and sprouts within their reach. Later, when cold weather set in and snow covered the ground, they also seriously damaged the trees.

White-footed mice (*Peromyscus michiganensis*) were especially numerous, but stomach examinations of individuals captured revealed no evidence that they had eaten bark of trees. Skunks, short-eared owls, and marsh hawks were common, no doubt attracted to the vicinity by the abundance of mice. From the large number of partly devoured dead mice found in the burrows during poisoning operations, I had reason to think that shrews (*Blarina brevicauda*) also were abundant. Of course living voles helped to devour the dead.

Previous to my visit a force of men and boys had been employed in painting the trunks of the trees with a wash composed of soap, crude carbolic acid, and water. The efficacy of this wash as a preventive of attacks of mice or rabbits did not extend beyond a period of forty-eight hours.

On the evening of my arrival I placed wheat poisoned with strychnine at the base of about 50 apple trees. On the next morning a large number of dead voles and white-footed mice were found. So favorably were the owners of the orchard impressed by the result that a force of men was employed to distribute poisoned grain throughout the orchard.

The poisoning operations in this orchard occupied several weeks, and by January, 1904, the mice apparently had been exterminated. Rabbits, however, continued to give trouble, and the campaign against them was continued for some time longer, with final success.

As a treatment for the trees injured by mice, I recommended the immediate covering of the wounds by mounds of soil heaped up around the trunks. The plan was adopted with highly satisfactory results. New bark grew wherever the cambium layer was not eaten completely through, and a great majority of the trees recovered. (Pl. VI, fig. 2.) Had their trunks been left exposed to the sun and winds of spring and summer most of them would have died. The number of trees actually killed by mice was not very great, although the growth of many was seriously checked.

Although at first the damages from mice seemed far more extensive than those from rabbits, the ultimate losses from them probably were less. The wounds from rabbits were too high up to be successfully covered with soil, and no remedy other than wrapping with paper was tried. The difference in the character of the injuries by these animals is well illustrated by Plate VII, which shows two dead trees—one killed by mice and the other by rabbits. Plate VIII and Plate VI, figure 2, illustrate injured trees in the same orchard which have fully recovered.

The following winter, 1904-5, mice and rabbits were again abundant in the orchard, having come in from adjacent territory. The experiences of the preceding winter were repeated, except that cover for mice was less dense and the campaign against them began much earlier in the season.

During the two winters named, many other orchards throughout eastern Kansas were seriously injured by field mice. As a rule no preventive measures were used, and the total losses were enormous.

THE RELATION OF FIELD MICE TO THE FARMER.

In 1886 the Biological Survey sent out a circular letter of inquiry about damages to crops by mammals.^a A great many replies from widely scattered places were received. The replies relating to field mice show that these animals everywhere are regarded as a pest.

The following extracts from letters on file in the office of the Bureau of Biological Survey are here presented to show not only how great is the amount of injury from field mice in certain localities, but to give an idea of the wide area over which losses are sustained.

REPORTS FROM FARMERS AND OTHERS.

Field mice are very injurious to clover fields. The injury is done by eating the roots when the ground is covered with snow. The loss is serious. They are injurious to fruit trees and yellow locust and Osage orange. They girdle them beneath the surface of the ground during deep snows. They destroy apple and pear trees, but rarely hurt peach and cherry.

—Gap, Lancaster County, Pa., Nov., 1886.

Field mice injure pastures and meadows by burrowing under grass roots and destroying them. There were more last summer than for years. I think, owing to the destruction of their natural enemies.

—Eastbrook, Lawrence County, Pa., Feb., 1887.

Meadow mice are very destructive to grain, grapes, and trees. This fall (November, 1886) three or four years ago, the fields were swarming with them. I went out with my little boy and we killed 56 in an orchard in less than two hours. In going half a mile from the station the dog picked up 15. They ruined several hundred fine apple trees for me, some of them several inches in diameter. Many thousand trees were ruined in this country. They prefer apple to plum or peach bark.

—Huron, Mich., Nov., 1886.

This has been a periodical year for their invasions and the damage has been great in many fields and meadows, particularly potato fields, which have been badly damaged where the surface was grassy. They injure to a slight extent cabbage buried in the ground. Clover fields and wheat have also been damaged. They do great injury to cornfields, eating the grain and even climbing up the stalk to the ears. All kinds of vegetables are eaten. Pastures are devastated for rods where the grass is high enough to hide the mice. Other invasions occurred in 1883 and 1888. Fruit trees are not injured except in cases where there is straw or other litter: then the trees are girdled by gnawing.

—Camp Point, Adams County, Ill., Nov., 1889.

^a Circular No. 3, On the Economic Relations of Mammals, 1886.

Meadow mice attack almost every tree and shrub. They girdle about everything, even rosebushes, blackberry, and raspberry bushes. I saw a willow hedge yesterday (April 8, 1889), 2 years old, with nearly every stalk girdled to 6 or 8 inches above the ground. They injure pastures and meadows and destroy root crops placed in heaps.

—Rochester, Mich., Apr., 1889.

Meadow mice destroy many trees and vines. The natural enemies of these mice are as much of a nuisance as the mice themselves.

—Frankfort, Mich., 1888.

Orchards here have suffered this winter from the depredations of the meadow mouse. I presume thousands of trees have been badly gnawed in this town alone. Still the war of extermination goes on against hawks and owls.

—Hammondville, N. Y., Apr., 1887.

They eat potatoes in the ground and corn in the shock. Do considerable damage to potatoes, sweet potatoes, and peanuts.

—Eubank, Ky., 1887.

Field mice destroy wheat by cutting off the stalks. Sometimes the loss is serious. They are also injurious to pastures and meadows.

—French Creek, W. Va., July, 1888.

Meadow mice sometimes injure meadows. They often do serious damage to trees and shrubs. Some seasons acres of young forest trees are barked. Maple and apple suffer the oftenest.

—La Crescent, Minn., Nov., 1886.

Meadow moles (voles) are present in greater numbers than ever observed before. These voles have totally ruined a great many clover meadows, strawberry patches, and pastures that were not eaten close. They have girdled hedges until they can not live, and I noticed one place where a white ash tree, 4 inches in diameter, was stripped of bark for 6 inches above the ground. They have dug into pits containing turnips and beets and devoured them completely. They promise to be with us next season in untold millions. Their presence is the more noticeable as eighteen months ago I tried to get a single specimen to send to the Department of Agriculture for identification and could not.

—Cardington, Ohio, Feb., 1890.

Field mice injure pastures and meadows by eating off the roots during winter. We are now suffering, and have been for two years, from invasions of field mice. We suffer a material loss by having the bark gnawed from most kinds of fruit trees by them during the winter.

—Gansevoort, N. Y., Feb., 1888.

Our country place in Maine is being overrun with mice, which nest in the ground and destroy all the plants by eating the roots or tops of the plants as soon as they appear.

—Letter from Baltimore, Md., May 16, 1904.

The summer and winter of 1883 this county was overrun with meadow mice. They destroyed thousands of apple trees, besides lots of young forest trees. Besides girdling trees, voles do meadow lands a good deal of injury by eating off the crowns of the clover plants. Three hundred dollars would not repair the damage done to an orchard near the station. In 1863 trees 6 inches in diameter were stripped of bark clear up to the limbs 4 or 5 feet from the roots.

—Huron County, Mich., Oct., 1886.

The meadow mouse is very prolific. Its presence varies at periods from a few to countless numbers. Long droughts and inclement winters as well as natural enemies probably affect their numbers.

—Kansasville, Wis., Sept., 1888.

They damage hay by cutting the grass into lengths the size of toothpicks.

—Tower, Minn., June, 1895.

Mice eat celery put up in the garden. They also eat roots of grass if there is a heavy snow on the ground during the winter.

—Lewisburg, Union County, Pa., Dec., 1886.

Mice often cause serious trouble in the winter season by girdling fruit trees, especially apple and peach trees. They commit depredations on buckwheat fields.

—Milan, Bradford County, Pa., 1888.

Our fields are subject to invasions of meadow mice during the winter when mulch is on them. A thousand of the mice wintered 1885-86 on a 2-acre strawberry patch. They eat the bark of trees when straw is placed about them or snow is on the ground.

—Mexico, N. Y., 1886.

Meadow mice injure dams, banks, drains, and embankments.

—Gilbertville, N. Y., 1887.

Meadow mice injure vegetables; they are especially fond of beets. They injure meadows quite seriously when numerous by feeding on grass roots. They were extremely numerous in 1885, and ate potatoes in the hills.

—Little Valley, N. Y., 1887.

In some cases I have found a shock of corn with half the corn consumed by meadow mice.

—Caldwell, N. J., Nov. 1, 1886.

The fields are full of mice. They are about the ears of standing corn, while that on the ground is mostly eaten. This is surely an invasion of mice. I can account for it only because last winter was so mild that all of them survived.

—Fairfield, Iowa, Nov., 1889.

Meadow mice are very destructive to the harvest fields, particularly in the shocks. They bite the ears of wheat and cut the twine bands off the sheaves. They gnaw young fruit trees in winter, if manure or straw is left close around the stem, and they kill the trees.

—Willows, Griggs County, Dak., Dec., 1886.

Field voles eat wheat, rye, and other cereals, both green and when matured, and carry green grain as well as matured kernels into their burrows. They sometimes carry a half bushel of grain into a single hole. They damage fodder by cutting it.

—North Topeka, Kans., May, 1890.

In the summer of 1884 we had an invasion of meadow mice [probably *M. townsendi*], and they did much damage. They destroyed seeds in the garden and ate growing wheat and oats in the spring, sometimes nearly destroying entire fields. They played havoc with the early peas and destroyed carrots and parsnips in the fall. The summer was unusually wet. The next summer was dry, and the mice disappeared. This is the only mouse year we have ever had here. During the year nearly all the cats died, apparently from eating the mice. They caught and ate them freely and were all affected alike. Some vomited more freely than others; they got puny, refused to eat, and died. Since the "mouse year" cats are themselves again.

—Aumsville, Oreg., Dec., 1886.

The bob-tailed mouse is a pest here, eating all kinds of bulbs, lilies, tulips, potatoes, etc.

—Centerville, Mo., 1887.

Meadow mice ruined nearly the entire crop of clover in the winter of 1884-85.

—Wakeman, Ohio, 1886.

We are troubled with meadow voles. When we have much snow in winter they are very plentiful the next summer. Winter thaws, which leave the fields bare of snow, destroy them. They destroy fruit trees by gnawing the bark

under the snow. I think they will eat the bark from any kind of young trees. The damage is serious.
—Montpelier, Vt., Nov., 1886.

Voles sometimes gnaw young apple and pear trees, mostly in winter; in summer also where red clover grows about the trees. The loss is serious.
—Salem, Ohio, 1886.

Meadow mice are injurious to meadows and pastures by cutting the sod in winter. We had an invasion of them in the winter of 1864, when they killed grape vines, raspberries, and crab-apple trees 5 inches in diameter.
—Stoughton, Wis., 1887.

Field mice are destructive to grain crops. Their depredations are mostly confined to the consumption of grain, but the injury by them depends upon the nut crop; if this is plentiful they do not disturb grain, or corn chiefly, but if there is a scarcity of nuts, they make incursions on the fields of corn, doing considerable damage.
—Columbia, Conn., Sept., 1887.

The majority of the preceding reports refer to the common meadow mouse (*M. pennsylvanicus*) and its subspecies, but some of them from the Middle West undoubtedly include references to the prairie vole (*M. ochrogaster*), which is more numerous there. Most of the destruction to potatoes and stored vegetables may be attributed to pine mice.

REPORTS FROM NURSERYMEN AND ORCHARDISTS.

Early in March, 1906, a circular letter of inquiry asking for information in regard to damages by field mice was sent to more than a thousand representative nurserymen and fruit growers in the United States and southern Canada. Up to April 10, 1906, replies returned number 520, of which a summary is presented in tabular form.

Damages by field mice, as reported by nurserymen and fruit growers.

State or province	Number of circulars sent.	Number of replies received.	Mice abundant.	Mice not abundant.	Mice absent.	Damage by mice serious.	Damage not serious.	Damage none.	Number who make estimates.	Total of damage estimates.
Maine.....	8	4	2	2	.....	2	1	1	2	\$125
New Hampshire.....	11	7	5	2	.....	4	3	.....	2	100
Vermont.....	6	2	1	1	.....	.....	2	.....	.....	.....
Massachusetts.....	40	23	11	12	.....	7	10	6	7	865
Rhode Island.....	6	4	.....	1	3	.....	1	3	.....	.....
Connecticut.....	22	11	7	4	.....	3	6	2	4	460
New York.....	85	34	24	9	1	20	7	16	8	8,275
New Jersey.....	23	12	6	6	.....	3	8	1	4	750
Pennsylvania.....	37	27	22	5	.....	13	11	3	15	3,100
Delaware.....	10	3	.....	3	.....	.....	2	1	.....	.....
Maryland.....	20	12	6	6	.....	3	4	5	2	35
Virginia.....	12	3	1	2	.....	.....	3	.....	.....	.....
West Virginia.....	9	6	2	4	.....	1	2	3	1	350
North Carolina.....	16	10	6	4	.....	4	2	4	1	3,000
South Carolina.....	3	1	.....	.....	1	.....	.....	1	.....	.....
Georgia.....	16	8	.....	2	6	.....	1	7	.....	.....
Florida.....	6	5	3	.....	.....	.....	.....	.....	.....	.....
Alabama.....	22	9	.....	5	4	.....	1	8	.....	.....
Mississippi.....	9	3	.....	1	2	.....	.....	3	.....	.....
Tennessee.....	18	7	2	5	.....	.....	2	5	1	25
Kentucky.....	30	18	3	15	.....	2	8	8	1	75

a Probably not *Microtus*.

Damages by field mice, as reported by nurserymen and fruit growers—Cont'd.

State or province.	Number of circulars sent.	Number of replies received.	Mice abundant.	Mice not abundant.	Mice absent.	Damage by mice serious.	Damage not serious.	Damage done.	Number who make estimates.	Total of damage estimates.
Ohio	51	24	13	11	.....	6	12	6	5	\$700
Indiana	40	20	7	13	.....	5	9	6	.....	.....
Illinois	56	29	19	8	2	14	8	7	12	4,800
Michigan	43	19	13	6	.....	7	8	4	5	1,400
Wisconsin	28	13	9	4	.....	6	4	3	6	6,825
Minnesota	27	22	17	5	.....	13	8	1	13	4,085
Iowa	49	26	22	4	.....	16	7	3	4	2,500
Missouri	38	25	16	9	.....	13	4	8	7	4,150
Arkansas	16	7	2	3	2	.....	2	5	.....	.....
Louisiana	10	6	.....	a2	4	.....	1	5	.....	.....
Texas	18	10	a3	6	1	.....	2	8	.....	.....
Oklahoma	14	6	.....	6	.....	.....	6	.....	.....	.....
Indian Territory	5	3	.....	3	.....	.....	.....	3	.....	.....
Kansas	46	27	12	15	.....	8	9	10	9	57,400
Nebraska	32	20	7	13	.....	6	7	7	3	350
South Dakota	16	7	2	5	.....	2	3	2	.....	.....
North Dakota	6	5	2	2	1	2	1	2	1	100
Montana	11	3	3	.....	.....	2	1	.....	1	500
Wyoming	1	1	1	.....	.....	.....	.....	.....	.....	.....
Colorado	10	3	1	1	1	.....	.....	3	.....	.....
New Mexico	4	1	.....	.....	1	.....	.....	1	.....	.....
Arizona	1	1	.....	.....	1	.....	.....	1	.....	.....
Utah	5	3	2	1	.....	1	2	.....	.....	.....
Nevada	0	0	.....	.....	.....	.....	.....	.....	.....	.....
California	18	10	2	3	5	1	1	8	.....	.....
Oregon	12	7	4	2	1	1	1	5	.....	.....
Idaho	8	4	3	1	.....	1	2	1	1	50
Washington	9	4	.....	4	.....	1	3	.....	2	75
Ontario	17	4	4	.....	.....	4	.....	.....	3	6,500
Quebec	2	1	1	.....	.....	1	.....	.....	.....	.....
Total	1,003	520	266	218	36	172	175	173	129	107,195

a Probably not *Microtus*.

Some comments on the above table are necessary. In reporting the abundance of mice nearly all the replies refer to present conditions. In many places where the animals are not now common they have been numerous in past years. In reporting damages many correspondents gave only personal experience, but did not answer the question as to damages in the neighborhood. Few of the persons who had sustained serious damages were able to estimate the amount of the losses, while many whose losses were slight made such estimates.

It will be noticed that in the South the injury from field mice is not serious, and that in the far West mice are troublesome in fewer localities than in the northern part of the country east of the Mississippi River.

Extracts from replies to the circular are here presented:

Field mice are abundant here. They have done me a great deal of damage during the past year, principally on overgrown stock that I have not cultivated, allowing grass to grow around the trees. They were also very destructive to a lot of young date palms (*Phoenix canariensis*) grown close together in a bed.

—West Berkeley, Cal.

Field mice are abundant here. We lost about 200 fruit trees from their attacks in 1903. Other orchards and nurseries in this section have been badly injured.

—Carlton, Mont.

Field mice are abundant in this vicinity, and in the winter of 1904-5 did much damage to orchards. In neighboring orchards, where girdling is claimed to be done by rabbits, I find that in five-sixths of the cases the injury is done by mice.
—Cokato, Minn.

We lost 2,000 trees in our orchards, not all killed—actual loss, about \$4,000.
—Topeka, Kans.

Mice are abundant here this winter, and have girdled 5,000 trees in the nursery.
—Moundsville, W. Va.

Field mice are abundant in North Carolina. On account of the general lack of snow in the vicinity of Raleigh they have not done serious damage to trees, but are very troublesome in gardens. The general observer charges moles with all the damage, but I have found that the mice, following in the mole runs, are the most serious enemies. Following under the sweet-potato ridges they gnaw the potatoes and do a great deal of damage. By using carbon bisulphid in the mole runs I destroyed more mice than moles, and became satisfied that the vegetable eating was mainly, if not entirely, done by the mice [pine mice].
—Raleigh, N. C.

In the winter of 1904-5 my loss in the peach orchard from mice was fully 10 per cent of the 1-year-old trees and 5 per cent of the 2-year-old. One 2-year-old peach orchard having turnips only on the ground was badly injured where snow was drifted. Another orchard in rather grassy corn stubble was injured in the same way. Peach seedlings in the nursery were also badly injured.
—Aspers, Adams County, Pa.

Young trees and nursery stock were damaged by mice in 1904-5 when the snow was deep. It is difficult to protect nursery stock. The common skunk destroys field mice, and protecting the skunk is the best preventive of injury of which I know.
—Collinsville, Hartford County, Conn.

Mice become worse every year, and it seems impossible to prevent damage now. This year, while there has been but little snow, they have damaged many trees. I have had 150 trees killed by mice in my orchard of 120 acres. They eat the bark from 8 inches below the surface of the ground to 12 or 15 inches above the ground.
—Council Grove, Morris County, Kans.

A lot of the trees heeled in the ground over winter and covered heavily with leaves were damaged by mice.
—Versailles, Ky.

During the winter of 1903-4 we had about 50 trees girdled in the orchard. Field mice seem to come as a scourge periodically. I can remember of from four to five seasons out of the past twenty-five when the pest was very, very numerous here. It seems almost incredible how all of a sudden they come and then seemingly mysteriously disappear. The country seems now to be almost free of them.
—Center Point, Iowa.

Considerable damage has been done in the nursery, particularly to seeds of trees and shrubs, and also in girdling young trees under heavy snow. The mice [pine mice] work under mulching on trees and, in mole runs, on seeds and roots of some plants.
—Saginaw, N. C.

No injury was noticed this open winter, but last year they girdled many young apple trees, both in the nursery rows and when heeled in.

Some few years ago this whole section suffered untold mischief by an unusual incursion of short-tailed field mice. They seemed to be everywhere, especially on roadsides and under hedges. While the snow lay deep they ate the bark from the roots of apple, locust, and some other trees, including the Osage orange.

This eating was always below the snow line or under cover of litter of any sort that hid the animals from the eyes of hawks and owls. These and foxes are their natural enemies.

The greatest absolute loss that season was in the destruction of red clover (*Trifolium pratense*). Many fields that went into winter with a beautiful aftermath of clover and other grasses came out in the spring bare of any profitable cover and had to be replowed, the clover roots having all been eaten out.

The favorite dainty with the mice is celery, when it is trenced in and covered with fodder.
—Colora, Cecil County, Md.

Field mice are abundant here. While I have personally had no losses of trees from them, very many orchards and nurseries in this vicinity have been nearly ruined, especially where they were neglected and grass and weeds were permitted to grow. I prevent loss by thorough cultivation and by mounding up soil at the base of the trees late in the fall.
—Boone, Boone County, Iowa.

I had perhaps 10,000 trees destroyed by mice and rabbits during the past five years, mostly by mice, in 1904 and 1905. Loss, \$2,000.
—Twin Bluffs, Wis.

Mice are abundant here. We have suffered no damage, but some young orchards have been completely ruined. They were left with quite a mulching of grass and cover. This made a harbor for the mice, and they girdled nearly all of the trees.
—Oakland, Kans.

We lost \$2,000 worth of nursery stock in 1904 and 1905.

—Rochester, N. Y.

We have a few thousand nursery trees destroyed by them each season.

—Charles City, Iowa.

Field mice abundant. My nurseries have been damaged to a great extent, especially last year during heavy snow.
—Ellisville, Mo.

During the winter of 1903-4 mice were very abundant throughout the valley and, indeed, in most of the State. The damage to nurseries and orchards was about 25 per cent. Shade trees, as well as apple, were injured. The following summer the mice were exceedingly abundant in clover fields. Early in the spring they greatly disfigured lawns in the city and in the cemetery by burrowing on the surface of the ground under the snow. [The species in the valley is *M. pennsylvanicus modestus*.]
—Bozeman, Mont.

Ten years ago we scarcely noticed any damage from mice. Some six years ago they began doing more or less damage and became very troublesome in the winter of 1903-4. They mowed off our two and three year old evergreens by the thousands, so that we had to rake over the beds before counting out trees to ship. We had piles of small trees the size of haystacks. I can not tell the money value, but think it much higher than I put it (\$2,000).

I laid the trouble in this section to hunters. Hawks, owls, minks, skunks, etc., used to be very plenty, but they have nearly all been killed. Their principal food is mice. A short-eared owl wintered near our sheds in an evergreen, and you could hardly believe the piles of mice skins under that tree in spring.

Two years ago a pair of weasels took up their abode in our tree cellar, breeding there last year. They kept most of the mice killed off. In the summer we saw the old one quite often carrying mice to its young from outside the shed. * * * This winter has been very mild, with no snow. Mice have been plenty in meadows, but grass kept green and tender, and they did our nurseries little damage.
—Waukegan, Ill.

ECONOMIC STATUS OF FIELD MICE.

The foregoing testimony as to the ravages of field mice sufficiently attests their noxious character. The extent to which they are beneficial to the farmer may be stated in few words. The upturning of the soil by gophers, ground squirrels, moles, earthworms, and various insects is an important part of its preparation for man's use, and field mice contribute to the work. In addition, mice diminish the number of weeds by eating the seeds and, possibly, occasionally devouring the roots.

The character of the vegetable matter eaten by field mice depends entirely upon the environment. If the animals live in swamps where rushes, sedges, and grasses useless to agriculture abound, their diet is confined to these, and the naturalist who investigates their food only in such surroundings may fall into the error of concluding that they are not injurious. But field mice at all times show a decided preference for cultivated plants and grains, if accessible, and in winter seek diligently for succulent roots and the green bark of trees.

REPRESSION OF FIELD MICE—NATURAL AGENCIES.

In view of their wide distribution and the nature of their habitats, the complete extermination of field mice is impossible. It is, however, entirely practicable to so reduce their numbers that crops shall be safe from serious attack. Before describing the methods which the farmer may use to destroy the animals, it is important to consider the natural agencies which aid in their repression.

CLIMATIC INFLUENCES.

Climatic conditions so strongly influence the natural increase of field mice that an understanding of their relation to such increase is important. It has been often noticed that the periods of greatest abundance of voles follow one or more open, warm winters succeeded by wet summers. If at the same time food—particularly grain—is abundant, the most favorable conditions for the increase of the animals are present, and the maximum number of young at a birth, as well as the maximum number of litters, are brought forth. When grain is abundant the young of some species are said to begin to reproduce when only 2 months old.

The continuance of favorable conditions for two or more years is sure to be followed by an enormous increase of field mice, with serious injury to crops.

Very cold winters without snow and summers of long droughts are unfavorable to the increase of field mice. Occasionally a severe frost following a heavy downpour of rain destroys nearly all field mice over large areas.

EPIDEMIC DISEASES.

Excessive multiplication of any mammal to the point of overcrowding is sure to be followed sooner or later by a fatal epidemic. Numerous instances of the prevalence of such diseases among rodents are known, and several of the historic mouse plagues were terminated by them. So complete was the destruction that several years of almost total absence of mice followed.

NATURAL ENEMIES OF FIELD MICE.

Prominent among the recognized causes for the great increase of rodent pests in recent years is the persistent destruction of the birds, mammals, and snakes that habitually prey upon them. Warfare against the natural enemies of noxious rodents is not confined to America. In the British Islands and on the Continent gamekeepers have systematically killed foxes, weasels, stoats, hawks, and owls, on the plea that they destroy game, and even farmers have joined in the warfare against the so-called "vermin." In America the same mistaken sentiment exists, and too often has led to ill-advised legislation against mammals and birds that are beneficial to the farmer. Wise measures for game protection can not be too highly commended, but ignorance of the true relations of animals and birds of prey to game is widespread even among lawmakers and sportsmen's clubs.

One of the most common mistakes made by sportsmen in the supposed interests of game protection is the offer of prizes for the destruction of alleged "game-destroying" mammals and birds. In one instance nine competitors for a club's prizes destroyed during twelve months 184 weasels, 48 foxes, 54 minks, 343 skunks, 15 great horned owls, 6 "common owls," and 148 hawks. The fact that only 21 owls were killed in an entire year by nine men trying for a record reveals a scarcity of these useful birds that is not complimentary to the intelligence of the community. The large number of skunks killed indicates ignorance or disregard of the usefulness of that animal in destroying insects and mice. Apparently, too, there was no discrimination as to the species of hawks destroyed, and it is probably safe to say that field mice in a single year have damaged the farmers of the region concerned a hundredfold more than the value of all the game and poultry saved through the offer of prizes.

The evidence presented to a committee of the British Board of Agriculture, who were investigating the Scottish vole plague of 1892, showed conclusively that in the affected district before the outbreak carnivorous animals and birds had been very scarce. The committee in their report emphasized the importance of protecting the birds, whose absence in the district in question was regarded as an important cause of the enormous multiplication of voles.

The chief natural enemies of field mice are (1) mammals, wild and domestic, (2) birds, and (3) snakes.

MAMMALS THAT DESTROY FIELD MICE.

WILD MAMMALS.

Among the wild mammals of the United States known to feed upon field mice are wolves, lynxes, foxes, badgers, raccoons, opossums, skunks, weasels, and shrews. A few of these feed upon mice habitually, and this habit, combined with their well-known service in destroying insects, compensates in great measure for the injuries they inflict in other ways.

Skunks are efficient in the destruction of mice and rats. The larger skunks (*Mephitis*), with about 17 species and subspecies, are distributed over most of the territory occupied by field mice. Their chief food is insects, but mice are second in importance on the bill of fare. Skunks not only search woods and meadows for mice but often come about barns and outbuildings in quest of the common mouse (*Mus musculus*) and brown rat (*Mus norvegicus*). While it is true that skunks sometimes destroy poultry, they do so much less frequently than is generally supposed. Comparatively few skunks learn to kill chickens, the habit being characteristic of the individual rather than of the species.

Of 36 skunks of the genus *Mephitis* whose stomachs were examined by the Biological Survey, two only, both captured in poultry houses, had eaten domestic fowls. There was no evidence that any of the 36 had destroyed game or small birds. The food consisted principally of beetles, grasshoppers, cicadas, crickets, rats, mice, and lizards. On account of their usefulness in destroying noxious insects and rodents, skunks deserve even more than the partial protection now afforded them by the laws of several States.

The habits of the little spotted skunks (*Spilogale*) are similar to those of the larger species. Like them, they are useful because they destroy insects and mice. Occasionally individuals learn to destroy domestic fowls, but the habit is even rarer than with the large skunks. As persistent and successful mousers about farm premises, they are unequalled and should be protected, the death penalty being reserved solely for the individuals that attack poultry.

The white-backed skunks (*Conepatus*) live in the South, mostly out of the range of field mice. They destroy many other kinds of rats and mice.

The mink (*Lutreola*) feeds commonly upon fish and other aquatic animals, but sometimes raids poultry kept near streams. It destroys meadow mice as well as other small rodents. The fur is in such demand, however, that minks are not likely to become sufficiently

numerous to have much effect, good or bad, upon the interests of the farmer.

The various species of weasels and wild ferrets are persistent destroyers of meadow mice. The smaller weasels easily traverse the surface runways of the larger species of *Microtus* and even follow them into underground burrows. The larger weasels feed upon pocket gophers, prairie dogs, ground squirrels, and various kinds of mice and rats. While occasionally they capture game or song birds, as well as poultry, their principal food consists of injurious rodents.

The small American weasels, like European species, have an evil reputation among game preservers and farmers, who assert that weasels destroy the eggs and young of game birds, as well as young chickens and other fowls. However, stomach examinations, supplemented by careful field observations, show that small mammals form the principal food of weasels. Among their prey are cottontail rabbits, little chief hares (*Ochotona*), prairie dogs, ground squirrels, wood rats, field mice, and the house mouse and brown rat.

A recent advance in the price of weasel skins in white, or winter, pelage has already caused a marked scarcity of these animals in some of the Northern States. The present abundance of meadow mice in the same States is attributable partly to the destruction of weasels. A correspondent in Minnesota, in a letter dated April 14, 1906, states that field mice were very abundant in his neighborhood during the preceding winter and caused much damage in orchards and nurseries. He adds: "The animals have never been so numerous here as during the last two years. I think weasels used to keep mice in check, but the high price of fur has made them very scarce."

Badgers, when not employed in unearthing larger rodents, devote much time and labor to digging out field mice. One will patiently excavate every burrow on an acre or more of ground, and, besides the litters of young, evidently get a large share of the old mice. Badgers have been caught with their intestines full of pellets of fur and bones of *Microtus*. Nevertheless, while doing almost no harm and while in general highly beneficial, badgers are destroyed almost everywhere, partly for sport, partly because on rare occasions one raids an unprotected chicken coop.

Foxes destroy many field mice and other rodents as well as many insects, especially grasshoppers, and thus do much to compensate for the poultry and game they kill. Although reliable testimony to the destruction of domestic fowls by the red fox (*Vulpes fulva*) is not wanting, the habit is by no means common, as is shown by the contents of stomachs examined by the Biological Survey. In three cases remains of the Gambel partridge were found and in one other a small bird. On the other hand, harmful rodents, including field mice, were found in over 20 stomachs. Besides these, a mole, a lizard,

grass, corn, blueberries, and cultivated grapes show a somewhat miscellaneous diet. A writer in *Forest and Stream* states that in the stomach of a gray fox (*Urocyon cinereoargenteus*), taken at Milford, Conn., he found rabbit hair, parts of a field mouse, sweet corn, pieces of apple, remains of a woodcock, and some leaves.^a

That shrews destroy many field mice is certain, although the evidence is largely circumstantial. It is known that they eat dead mice that have been caught in traps. It is proved that they are able to capture a live field mouse in its burrow by the fact that when both animals are confined in the same cage the shrew kills and partly eats the other animal. Shrews are often trapped in the burrows of field mice, and it is highly probable that they habitually feed upon the rodents. As they eat only the flesh and blood of their victims it is difficult to identify their food by stomach examinations.

The common brown rat (*Mus norvegicus*) is an enemy of field mice where both occur in the same locality. On the Potomac flats, south of Washington, D. C., both rats and meadow mice (*M. pennsylvanicus*) are abundant. On various occasions, while trapping mice there, specimens in small cage traps were destroyed by rats. Several times I had occasion to uncover burrows and runways of the mice by removing piles of dry weeds. On the following mornings I found that rats had enlarged the burrows in pursuit of mice, and the remains of fur and stains of blood on the ground showed that the pursuit had been successful. It is unfortunate that rats are even worse pests than the field mice they destroy.

Of the other wild mammals that destroy field mice—wolves, coyotes, lynxes, raccoons, and opossums—it may be said that the mouse-eating habit is not always prominent and that their economic status can not be determined by it alone. On the whole, however, their general effect in checking the increase of rodents must be regarded as an important item to their credit.

DOMESTIC MAMMALS.

Some of the domestic animals assist in the destruction of field mice. Cattle and horses in pastures undoubtedly trample upon and destroy many mice, especially the young. Hogs in fields and wood lots root them from burrows and nests and eat them. Aristotle mentions the ancient practice of turning swine among mice "to root up their runs."^b But the more important of their enemies among domestic animals are dogs and cats.

Dogs follow the farmer to the field and at plowing and harvest are ready to pounce upon and kill every mouse that is uncovered in fur-

^a *Forest and Stream*, vol. 55, p. 464, Dec. 15, 1900.

^b Aristotle's *History of Animals*, Book 6, chap. 30, p. 178, Bohn's edition, London, 1862.

row or shock. While they seldom eat rats or house mice, they sometimes become very fond of field mice and learn to hunt them independently. A good rat dog is undoubtedly a valuable asset of the farm, and I have known one to keep premises clear of brown rats (*Mus norvegicus*) when adjoining farms were overrun with them.

Many cats are good mousers, both in house and field. Some live largely upon pocket gophers, ground squirrels, and field mice. Unfortunately, however, when cats roam afield they learn to destroy song birds, young poultry, and game. The ordinary farm cat is exceedingly destructive to small birds and game, and the number that cats annually kill is immense.

House cats usually are too well fed to make good mousers, and are believed to aid in the spread of infectious diseases among human beings. In spite of the usefulness of individual cats in destroying mice, every community would be better off for a large reduction in its feline population.

BIRDS THAT DESTROY FIELD MICE.

Many species of birds destroy rodents. Among those that eat field mice are shrikes, cuckoos, crows, herons, bitterns, storks, ibises, gulls, hawks, and owls. Unlike the mammals already named, some of these birds live almost exclusively upon field mice, and hence are of great assistance in reducing their numbers.

BIRDS OF PREY.

At the head of the list of bird enemies of field mice stand the hawks and owls. Most of the species habitually feed upon rodents, a few of them almost entirely. Moreover, the species that feed least upon harmful rodents feed largely upon insects. Thus the beneficial character of hawks and owls as a group is beyond question.

Fortunately the economic status of American hawks and owls does not rest upon mere theory or general assertions without proof. Bulletin No. 3 of the Biological Survey^a deals with the food habits of hawks and owls of the United States, and is based upon examinations of nearly 2,700 stomachs. Such large series of the more common species were examined that further investigations can but confirm and emphasize the present verdict—that American hawks and owls, as a whole, are among the best friends of the farmer and that only a few species are more harmful than beneficial.^b

^a The Hawks and Owls of the United States in their Relation to Agriculture, by A. K. Fisher, M. D., Washington, 1893.

^b Doctor Fisher's report on the food of hawks and owls has long been out of print. For this reason some of the more important summaries of results, especially those relating to the mammal food, are given in this paper. Circular 61, Bureau of Biological Survey, Hawks and Owls from the Standpoint of the Farmer, gives a brief summary of the original report by Doctor Fisher, and may be had on application.

HAWKS.—Though hawks are our most common birds of prey, many kinds are too rare to exert a marked effect, either injurious or beneficial, upon the interests of the farmer; but the most common kinds are widely distributed and their voracious appetites make them of considerable economic importance. Nearly all hawks feed more or less upon rodents, and their most frequent victims are the short-tailed field mice.

The marsh hawk, or harrier (*Circus hudsonius*), is probably the most common and most widely distributed North American species. It is of medium size and may easily be recognized, while flying low over fields and meadows, by its conspicuous white upper tail coverts. The results of an examination of 124 stomachs of this species are as follows: Seven contained poultry or game; 34, small birds; 57, mice; 22, other mammals; 7, reptiles; 2, frogs; 14, insects; and 8 were empty. Field mice were positively identified in 44 stomachs, averaging almost two to each stomach. Eight were found in one stomach. The other mammals were mainly ground squirrels (spermophiles) and rabbits.

The buzzard hawks (genus *Buteo*) include seven species and six subspecies, all rather large and slow of wing. They are rarely able to capture a domestic or wild fowl. They live chiefly on small mammals, insects, snakes, and batrachians. The group includes such well-known birds as the red-tailed hawk (*Buteo borealis* and four subspecies), red-shouldered hawk (*Buteo lineatus* and two subspecies), Swainson hawk (*Buteo swainsoni*), and broad-winged hawk (*Buteo platypterus*).

A summary of the food of 562 red-tailed hawks is as follows: Fifty-four of the stomachs contained poultry or game birds; 51, other birds; 278, mice; 131, other mammals; 37, batrachians and reptiles; 47, insects; 8, crayfish; 1, centipedes; 13, offal; and 89 were empty. Two hundred and twenty-eight stomachs contained 350 field mice.

Of 220 stomachs of the red-shouldered hawk 3 contained poultry; 12, other birds; 102, mice; 40, other mammals; 20, reptiles; 39, batrachians; 92, insects; 16, spiders; 7, crayfish; 1, earthworms; 2, offal; 3, fish; and 14 were empty. Sixty-three stomachs contained 89 field mice.

Of Swainson hawks, 18 stomachs were examined. Of these 7 contained small mammals; 8 contained insects; 3, reptiles; 3, batrachians; and 3 were empty. One of the mammals was a mouse, and nearly all the insects were locusts and grasshoppers. Throughout its summer range this species lives almost entirely upon grasshoppers.

Of broad-winged hawks, 65 stomachs were examined, 15 of which contained mice, and 13 other small mammals. No poultry or game birds were found in the stomachs, and the chief food was insects.

The most common Old-World representative of the genus is *Buteo buteo*, the common buzzard of England, and popularly known in Germany as the mouse buzzard (*Mäusebussard*). That the last name is well deserved, is shown from the researches of Dr. G. Rörig, of Berlin, who in 784 stomachs of this species found no less than 1,124 rodents, of which 1,057 were the common field mouse (*M. arvalis*).^a

Two prominent species of rough-legged hawks (*Archibuteo*) occur in America. Both are winter sojourners with us. The northern form, the common rough-leg (*Archibuteo lagopus sancti-johannis*), summers north of the United States. The ferruginous rough-leg (*A. ferrugineus*), commonly known as the squirrel hawk, nests extensively in the Western States, but is more common there in winter. Both species are large and may be easily distinguished by the feathering of the legs, which extends to the base of the toes. Doctor Fisher examined 50 stomachs, all but 1 being of the common rough-leg. Of these, 40 contained mice only; 5, other mammals; 1, insects and a lizard; and 4 were empty. Of the 40 containing mice, 28 had meadow mice only, the number varying from 1 to 8 and the average being more than 3 to each hawk. These are winter records. In summer the birds doubtless are largely insectivorous. It is certain that the rough-legs do not often molest wild birds or domestic fowls.

The researches of Doctor Rörig make an equally favorable showing for the Old World rough-legged hawk (*Archibuteo lagopus lagopus*). He examined 250 stomachs of that species and found remains of 879 rodents, mostly field mice. Ninety-four per cent of the birds examined by him had eaten injurious rodents.^b

The true falcons (genus *Falco*) of North America comprise 17 species and subspecies, of which 3 are accidental visitors from abroad, and several others, notably the gyrfalcons, are exceedingly rare within the United States. The various falcons differ much in size, but all are strong and swift of wing. The larger species destroy poultry and game, while the smaller kinds prey upon small birds and insects. All feed to some extent upon mice. The most common species are the duck hawk (*Falco peregrinus anatum*), the prairie falcon (*Falco mexicanus*), the pigeon hawk (*Falco columbarius*), and the sparrow hawk (*Falco sparverius*).

The duck hawk is a rather large falcon, and, as its name implies, preys much upon waterfowl. It destroys also game birds, domestic fowls, pigeons, and small birds. Although it feeds to some extent also upon insects and mice, the habits of the species, on the whole, do not commend it to the protection of farmers and sportsmen.

^a Arb. Biol. Abteilung für Land- und Forstwirtschaft, IV Band, 1 Heft, p. 64, 1903.

^b Arb. Biol. Abteilung für Land- und Forstwirtschaft, IV Band, 1 Heft, p. 74, 1903.

The prairie falcon inhabits the West and Southwest. Its habits are somewhat similar to those of the duck hawk. It feeds largely upon land birds, mammals, and insects. Game birds and tame pigeons are known to be on its "bill of fare."

The pigeon hawk is smaller than either of the two preceding species, and is widely distributed in North and Middle America. It nests chiefly north of the forty-third parallel, except in the higher mountains. It feeds mainly upon small and medium-sized birds, a few field mice, and insects (chiefly dragon flies and grasshoppers). Fortunately for our summer song birds, the pigeon hawk for the most part is migratory within the United States. However, it accomplishes some good by destroying English sparrows.

The sparrow hawk is the commonest of our falcons. While it destroys some small birds, its chief food is insects and mice. It is too small to do much injury to poultry and game, and many of the small birds it captures are the injurious European sparrow. Doctor Fisher's report gives the results of examinations of 320 stomachs of the sparrow hawk. Of these, 1 contained a quail; 53, small birds; 89, mice; 29, spiders; and 29 were empty. The insects were largely grasshoppers, and about half of the mice were field mice.

Two common hawks of the genus *Accipiter* should be mentioned—the Cooper hawk (*Accipiter cooperi*) and the sharp-shinned hawk (*A. velox*). Both destroy many birds and feed only to a small extent upon injurious mammals and insects. The Cooper hawk destroys much poultry and game, while the sharp-shinned hawk lives chiefly upon smaller birds, including quail and young chickens. Although both species prey upon meadow mice, their limited usefulness in this respect does not offset their injurious habits. The thieving traits of these two birds has had much to do with the undeserved ill repute in which hawks as a whole are held.

All the other American hawks and eagles prey to some extent upon field mice. The kites (four species) are highly insectivorous. The Mississippi kite (*Ictinia mississippiensis*), known sometimes as the blue hawk, is locally abundant as a summer resident in southern Kansas, in Oklahoma, and parts of Texas. Its food is almost exclusively grasshoppers, and it seldom molests birds, yet it is often wantonly destroyed by sportsmen simply because it is a hawk and offers a tempting mark. The same may be said of the other kites, including the beautiful and useful swallow-tailed species.

The chief economic function of hawks seems to be the destruction of harmful rodents and insects. A majority of the species are decidedly useful, their good qualities far outweighing the bad. A few have no harmful habits, but are wholly beneficial. A smaller number have good and bad traits nearly balanced, or certain species may be beneficial in some localities but harmful in others. Two common

species—the Cooper and sharp-shinned—destroy so many birds and poultry as to far outweigh any good they may do. If legislation against hawks is needed, which is more than doubtful, careful discrimination should be exercised as to the species placed under ban, and corresponding protection should be given those that are of undoubted benefit to the farmer.

OWLS.—Owls are preeminently enemies of mice. Their eyes are adapted to twilight and nocturnal hunting, and they prey mostly upon animals that are active after sunset. Noiseless of wing and possessed of sharp talons and much strength, they attack small mammals with great success.

Owls, and also hawks and some other birds that eat small vertebrates by swallowing them entire, are unable to digest the bones, fur, and feathers. These are thrown up in the form of pellets, the bones being surrounded by fur and feathers. Much of our knowledge of the food of owls is derived from examinations of these pellets.

The American barn owl (*Strix pratincola*) is rather common in the southern half of the United States, breeding as far north as forty-one degrees. In part of its range field mice are common and it preys upon them to a considerable extent. Examinations of 39 stomachs of barn owls were made by Doctor Fisher. Of these, 1 had eaten a domestic pigeon; 3, other birds; 17, mice; 17, other mammals; 4, insects; and 7 stomachs were empty. Meadow mice were found in 9 of the stomachs. The mammals eaten, other than mice, were chiefly ground squirrels (spermophiles) and other injurious species.

Doctor Fisher records the results obtained from an examination of 675 pellets of the barn owl collected at Washington, D. C. They contain remains of 1,731 rodents, 56 insectivorous mammals, 32 birds, and 2 frogs. The rodents were mainly rats (*Mus norvegicus*), house mice (*Mus musculus*), and meadow mice (*Microtus*). Of the last there were 1,123 skulls, or an average of almost 2 to each pellet.^a Doubtless similar investigations in California, where these owls are common, would show that there spermophiles are the chief food.

The habits of the European barn owl (*Strix aluco*) serve to illustrate further the usefulness of our own bird. Dr. Bernard Altum, a German naturalist, in 1863 recorded the results of examinations of 703 pellets of the barn owl. He found remains of 16 bats, 933 rodents, 1,479 shrews, and 22 small birds (19 of which were sparrows). Of the rodents 693 were voles.^b Later (1867) he published the results of examinations of 360 additional pellets, making 1,063 in all. The total shows 2,151 insectivorous mammals, and 1,801 rodents, of which 1,284 were voles.^c

^a Science, N. S., vol. 3, pp. 623-624, Apr. 24, 1896.

^b Journal für Ornithologie, vol. 11, pp. 41-46, 217-219, 1863.

^c Zoologische Garten, vol. 8, pp. 263-264, 1867.

The Reverend Doctor Jäckel, of Windsheim, Bavaria, collected and examined a total of 6,512 pellets of the barn owl. In them he identified skulls of 5,210 shrews and 14,790 rodents, of which 9,046 were *Microtus*.^a Doctor Rörig more recently examined 121 pellets of barn owl and in them identified 291 voles, 68 true mice, 35 shrews, and 13 sparrows,^b a result more in harmony with Doctor Fisher's tables.

John Watson calculates that each pair of owls of this species while feeding their young capture at least 40 mice per day. Once he found no fewer than 17 recently killed field mice on the side of a barn owl's nest which contained 5 young owls.^c The late Edward Newman stated that every owl of this species is worth £5 per year to the British nation.^d

The long-eared owl (*Asio wilsonianus*) is distributed throughout temperate North America, except the treeless plains. It is a constant resident over most of its range, and its usefulness in the destruction of mice continues throughout the year. Of the 107 stomachs examined by Doctor Fisher, 1 contained a quail; 15, other birds; 84, mice; 5, other mammals; 1, insects; and 15 were empty. Of the 84 containing mice, 46 contained specimens positively identified as meadow and pine mice. About 50 pellets cast up by long-eared owls contained 176 skulls, representing 93 meadow mice, 19 pine mice, 23 other mice, 26 shrews, and 13 small birds.

The long-eared owl (*Asio otus*) of the Old World has a similar record. Doctor Rörig made 108 stomach examinations of this species. In the stomachs he identified 20 small birds, 1 weasel, 2 bats, 18 shrews, 29 true mice, 14 bank voles (*Erotomys*), and 365 field mice (*Microtus*). Nine stomachs contained insects. Eighty-four per cent of the birds had eaten mice. A single stomach contained 12 field mice.

In 142 pellets of *A. otus* examined by Doctor Altum, he found 3 small birds, 2 shrews, 14 true mice, 12 bank voles, and 259 voles (1 *M. amphibius*, 65 *M. agrestis*, and 193 *M. arvalis*).^e Doctor Rörig examined 1,053 pellets of long-eared owl and found remains of 14 small birds, 1 frog, 2 moles, 29 shrews, 22 true mice, 15 bank voles, and 1,764 voles. Selby found 5 mice in a single stomach of this species.

The short-eared owl (*Asio accipitrinus*) is probably the greatest enemy of field mice. It figures in many historical accounts of vole plagues in England and on the Continent. Holinshed's Chronicle closes the account of voles in Danesey Hundred, of the county of

^a Zoologische Garten, vol. 15, p. 469, 1874.

^b Arb. Biol. Abteilung für Land- und Forstwirtschaft, IV Band, 1 Heft, pp. 102-104, 1903.

^c Ornithology in Relation to Agriculture and Horticulture, p. 12, London, 1893.

^d Hardwicke's Science Gossip, vol. 29, pp. 89-90, 1893.

^e Journal für Ornithologie, vol. 12, pp. 429-434, 1864.

Essex, in 1581, by saying: "Which vermin by policie of man could not be destroyed, till at the last there flocked together such a number of owles as all the shire was not able to yield, whereby the marsh holders were shortly delivered from the vexation of the said mice." Similar testimony as to the efficiency of owls as destroyers of voles is contained in other chronicles, and in the account of later outbreaks the species is definitely stated to be the short-eared owl.

The short-eared owl inhabits the temperate parts of both continents. In each its range extends northward well beyond the Arctic Circle. It is an irregular migrant and always appears in large numbers where voles, lemmings, or other mice become unusually abundant. It nests on the ground in tall grass, usually in moist meadows, a habitat peculiarly fitted for the operations of this consumer of meadow mice. Doctor Fisher reports the results of examinations of 101 stomachs of this species. Of these, 11 contained small birds; 77, mice; 7, insects; and 14 were empty. In the 77 stomachs that contained mice fully a hundred field mice were identified. Doctor Rörig examined 51 stomachs of this species and found in them remains of 90 injurious rodents, of which 76 were *Microtus*. He examined also 480 pellets of this owl, finding remains of 3 beetles, 9 small birds, 7 bank voles, 22 *Microtus agrestis*, and 842 *M. arvalis*.

For purposes of comparison, the results of the examinations of owl pellets are here presented in tabular form. The figures, disregarding fractions, represent the average number of individual mammals and birds found in 100 pellets of each species of owl.

Kind of mammal or bird found in owl pellets.	Barn owl.				Long-eared owl.			Short-eared owl— <i>Asio accipitrinus</i> (Dr. Rörig).
	<i>Strix nebulosa</i> (Dr. Fisher).	<i>Strix aluco</i> (Dr. Altum).	<i>Strix aluco</i> (Rev. Jäkel).	<i>Strix aluco</i> (Dr. Rörig).	<i>Asio wissonianus</i> (Dr. Fisher).	<i>Asio otus</i> (Dr. Altum).	<i>Asio otus</i> (Dr. Rörig).	
Harmful rodents:								
<i>Mus</i> (rats and mice)	87	48	87	56	46	10	2	0
<i>Microtus</i> (field mice)	166	121	139	241	114	182	168	180
Other rodents	3	a 4	a 1	0	0	a 8	a 2	a 1
Insectivorous mammals (shrews, moles, and bats)	8	202	80	29	52	1	3	0
Small birds (sparrows, etc.)	5	3	(b)	11	26	2	1	2

a Bank voles (*Eutamias*).

b Not given.

The barred owl (*Syrnium carium*) is larger than the species already considered. It resides throughout eastern North America from Nova Scotia to the Gulf and westward to the treeless plains. It usually lives in rather dense forests and swamps and nests in hol-

low trees. Owing to its greater size, its food includes larger mammals and birds than that of the last three species. Thus, it is able to carry off a good-sized domestic fowl, and no doubt occasionally it raids poultry. However, Doctor Fisher's examination of 109 stomachs of this species indicates that it is far less harmful than is generally supposed. Five stomachs contained poultry or game; 13, other birds; 46, mice; 18, other mammals; 4, frogs; 1, lizard; 2, fish; 14, insects; 9, crayfish; and 20 were empty. Field mice were positively identified in more than half of the 46 stomachs that contained mice.

The great horned owl (*Bubo virginianus*) is the largest owl resident in the United States. Its range, including the subspecies, extends from Costa Rica to the northern limit of deep forests and from ocean to ocean. In South America occur a number of closely related forms.

The great horned owl has an evil reputation with most farmers on account of its destruction of poultry. The bad reputation is only partly merited. Doctor Fisher examined 127 stomachs of this species. Of these, 31 contained poultry or game birds; 8, other birds; 13, mice; 65, other mammals; 1, a scorpion; 1, a fish; 10, insects; and 17 were empty. About half the mice found were meadow voles and the majority of the "other mammals" were rabbits. In central Kansas, some years ago, I examined over a dozen nests of this species in which young were being fed. The nests contained rabbits (*Lepus floridana mearnsi*), fox squirrels (*Sciurus ruficenter*), wood rats (*Neotoma baileyi*), skunks (*Mephitis*), field mice, and in two cases feathers of the flicker (*Colaptes auratus luteus*), but in no case any feathers or remains of poultry. In the few cases in which these owls were observed by me to raid poultry the fowls were roosting upon trees late in the fall, and hence were unnecessarily exposed to attack. Where rats are abundant this owl has been known to prey largely upon that rodent. O. E. Niles, in a letter to Charles Dury, dated March 5, 1885, stated that at one time the remains of no less than 113 rats had been counted under the nest of a great horned owl.^a On the whole, the great horned owl is not a very harmful species, and as it is rapidly disappearing in most parts of the United States warfare against it may be suspended.

The screech owl (*Otus asio*) is probably the most familiar of American owls. Including its ten or more geographic races, it has a wide distribution. It is too small to prey upon domestic fowls or game and is beneficial. Doctor Fisher reported on the contents of 255 stomachs, of which 1 contained a tame pigeon; 38, other birds; 91, mice; 11, other mammals; 6, lizards and batrachians; 1, fish;

^a Jour. Cin. Soc. Nat. Hist., vol. 8, p. 63, 1885-86.

100. insects: 5. spiders: 9. crayfish: 11. miscellaneous; and 43 were empty. A good proportion of the "other birds" were English sparrows. About a third of the mice were identified as meadow mice, while 24 were house mice. The large proportion of insects eaten is remarkable.

The burrowing owl (*Speotyto cunicularia hypogaea*) is a small species, common on western plains, and noted for its abundance during summer in prairie-dog "towns," where it occupies the deserted burrows of that rodent. Of 32 stomachs of this owl examined by Doctor Fisher, 2 contained mice; 1, a prairie dog; 3, lizards; 3, scorpions; 1, a centipede; 30, insects, and 1 was empty. The species is largely insectivorous and undoubtedly highly beneficial.

Several other species of owls occur in the United States, but at no season are they abundant over any considerable area. Probably all feed largely upon meadow mice. Doctor Fisher's report covered only a small series: but 6 out of 9 great gray owl stomachs, 4 out of 22 sawwhet owl stomachs, 10 out of 38 snowy owl stomachs, and the single hawk owl stomach examined contained the remains of field mice.

From the testimony of Doctors Fisher, Altum, Jäckel, and Rörig, and careful observations by others, the great value of owls for reducing the number of meadow mice is established beyond doubt, and the various species should everywhere be protected by legal enactments.

CROWS.

Among the most formidable bird enemies of field mice are the larger members of the crow family (*Corvidæ*). The fact that ravens, hooded crows, and rooks in the Old World feed upon voles and lemmings has often been noted. American crows have similar habits and feed upon field mice whenever occasion offers. Besides the common crow (*Corvus brachyrhynchos*) the list of mouse-eating crows includes the fish crow (*Corvus ossifragus*), the northwest crow (*Corvus b. caurinus*), the raven (*Corvus corax sinuatus*), and the white-necked raven (*Corvus cryptoleucus*). Magpies and the larger jays also destroy mice to some extent.

The food habits of the common crow form the subject of Bulletin No. 6 of the Biological Survey.^a The results of examinations of 909 stomachs of crows are tabulated in the report. Of this number, 78 contained mice, they being fourth in order of importance on the list of animal food for the year. Professor Barrows says: "There is abundant proof from several sources that crows often capture living mice, particularly the short-tailed field mice, which build their nests usually on the surface of the ground among the roots of grass. Here the crows discover them, and, tearing the nest to pieces, de-

^a The Common Crow of the United States, Walter B. Barrows and E. A. Schwartz, 1895.

your the young and not infrequently catch the adults as well. By far the greater number of the mice found in the stomachs were meadow mice, or voles (genus *Microtus*), and most of them were the common species (*Microtus pennsylvanicus*)."

In midwinter, when the ground is covered with snow, crows find but few field mice; but as spring approaches and the snow begins to melt on the meadows, the bulky grass nests of the mice are first exposed. The crows may then be seen searching the meadows for them. They alight near the openings in the snow, pounce upon the nests, tear them to pieces, and as the mice scamper out the crows often succeed in capturing them. Later in the spring, when crows feed their nestlings, insects are more abundant and the nests of mice are hidden in the growing grass, so that relatively fewer mice are eaten. Still later, after the young crows have left their nests and mowing machines have once more exposed mouse nests in the meadows, crows again spend much time searching for young meadow mice.

It is of interest to note that complaints of recent depredations of field mice are especially numerous from sections of the United States where for several years past bounties have been paid for killing crows.

CUCKOOS AND SHRIKES.

The larger species of the family of cuckoos (*Cuculidae*) are known to feed extensively upon vertebrates. The two more common cuckoos of the United States are too small to share this habit, but the road-runner (*Geococcyx californianus*) of the Southwest feeds rather commonly on reptiles, batrachians, and small rodents. Prof. F. E. L. Beal captured one in California which had eaten a field mouse (*M. californicus*).

The great northern shrike (*Lanius borealis*) is a common winter visitor in the northern half of the United States. It arrives from the north in October and remains until March or April. It is a familiar bird to most residents of rural districts. Gray in general color, with black wings, conspicuously barred with white, and with white in the tail, it looks much like a mocking bird, but has a strong, sharply-hooked bill, which enables it to kill small birds and mice. In its summer home it is probably much more insectivorous than with us. It comes to the United States at a time when insects are not abundant, and feeds mainly upon small birds, mammals, and grasshoppers. Mice were found in one-third of the stomachs examined by the Biological Survey and more than half of those identified were meadow mice. Doctor Mearns is quoted^a as authority for the statement that in Minnesota during March shrikes live almost exclusively on meadow mice. Most farmers have noticed that the northern shrike, or "butcher bird," catches meadow mice. The birds are often seen at

^a Bulletin 9 of the Biological Survey, Cuckoos and Shrikes in their Relation to Agriculture, p. 19, 1898.

husking time as they hover in the air or sit on a fence post or top of a hedge, ready to pounce upon every mouse that escapes from corn shocks as they are torn down or moved.

The smaller shrikes (*Lanius ludovicianus* and subspecies) also somewhat resemble mocking birds in color. They are summer residents of many parts of the United States. As insects are abundant during the greater part of their stay, they are insectivorous to a greater extent than the northern shrike. Stomach examinations prove that mice form 16 per cent of the food for the entire year, but the birds are less able than the larger species to cope successfully with adult meadow mice, yet they undoubtedly destroy a good many voles, and several have been identified in their food; but smaller mice are more frequently caught.

Although shrikes destroy a few useful birds, they more than compensate for this by their destruction of small rodents and insects, and they fully merit protection by the farmer.

OTHER BIRDS.

Members of the order *Herodiones*, including herons, storks, and ibises, are usually persistent enemies of meadow mice. Many of them frequent meadows and swamps, especially in the breeding season. Unfortunately, the summer range of the larger number of species is too far south to bring them much in contact with voles. However, a few species spend the summer where mice abound and make them an important part of their food.

Of our herons, the American bittern (*Botaurus lentiginosus*) is probably the best known destroyer of voles. The bird is a summer resident in all suitable localities in temperate North America, making its home in moist meadows, bogs, and swamps. Baird, Brewer, and Ridgway say of it: "It does not move about much by day, although it is not strictly nocturnal, but is sometimes seen flying low over the marshes in pursuit of short-tailed or meadow mice, which are frequently taken whole from its stomach."^a Records of the Biological Survey contain a number of instances in which meadow mice were found in stomachs of this species.

Among other *Herodiones* that feed upon meadow mice are the least bittern (*Ardetta exilis*), wood ibis (*Tantalus loculator*), great blue heron (*Ardea herodias*), American egret (*Herodias egretta*), snowy heron (*Egretta candidissima*), and the black-crowned night heron (*Nycticorax nycticorax neriuss*). While frogs, fish, and fresh-water crustaceans form the major portion of their food, they feed also upon mice, shrews, and other small mammals. As a group they undoubtedly effect a reduction in the numbers of meadow mice in America.

During a plague of field mice (*Peromyscus* in this case) in South America in 1872-73 Mr. W. H. Hudson observed that storks became

^a The Water Birds of North America, vol. 1, p. 70, 1884.

very numerous. He says: "In the autumn of the year [May, 1873] countless number of storks (*Ciconia maguira* [*Eurycnura maguira*]) and short-eared owls (*Asio accipitrinus*) made their appearance. They had also come to assist in the general feast. * * * Years have perhaps passed during which scarcely an individual of these kinds has been seen; all at once armies of majestic white storks are seen conspicuously marching about the plain in all directions, while the night air resounds with the solemn hootings of innumerable owls."^a European writers bear testimony to the usefulness of the common stork (*Ciconia ciconia*) in destroying voles and other kinds of mice.

The family of cranes (*Gruidæ*) range farther north than the herons, and the three North American species are known to feed to some extent upon voles, capturing both young in the nests and adults. The habitat of cranes includes upland prairies as well as moist meadows, and thus probably they prey upon more species of voles than herons do.

Although the usual food of gulls (*Laridæ*) consists of fishes and insects, they feed also upon rodents. During the vole outbreak in Scotland in 1892 several species of gulls, notably the great black-backed gull (*Larus marinus*), fed upon the field mice; and gulls are usually named among the species that feed upon lemmings during their migrations. It is highly probable that the larger American gulls feed upon field mice whenever they find them.

SNAKES.

Snakes must be included among the natural enemies of field mice. While nearly all snakes feed extensively upon insects, many of them eat vertebrates, including fishes, reptiles, batrachians, birds, and mammals. The larger bull snakes (*Pituophis*), black snakes (*Callopeltis*), and rattlesnakes (*Crotalus*) of the United States feed largely upon mammals, including rabbits, prairie dogs, pocket gophers, and ground squirrels, as well as different species of rats and mice. Black snakes and bull snakes probably kill more field mice than the others; but black snakes destroy also a considerable number of nestling birds and birds' eggs, so that part of their beneficial work is offset by this injurious habit. A nurseryman in Pennsylvania reports that he secured immunity from mice in his nursery by turning loose in it 50 black snakes. On the whole, snakes, except the venomous species, are deserving of the farmers' protection. Like the toad, the smaller kinds feed almost wholly upon insects; but an inherent prejudice induces thoughtless people at every opportunity to destroy these friends of agriculture.

^a Naturalist in La Plata, pp. 64-65, 1892.

REPRESSION OF FIELD MICE—ACTIVE MEASURES.

We pass now to a consideration of such means for the repression of voles as are under the immediate control of the farmer. These consist of trapping and other mechanical methods of destruction and the use of poisons, fumes, and micro-organisms.

TRAPPING.

Trapping is a simple way to destroy field mice, but it is seldom resorted to because few people have patience to follow it up per-

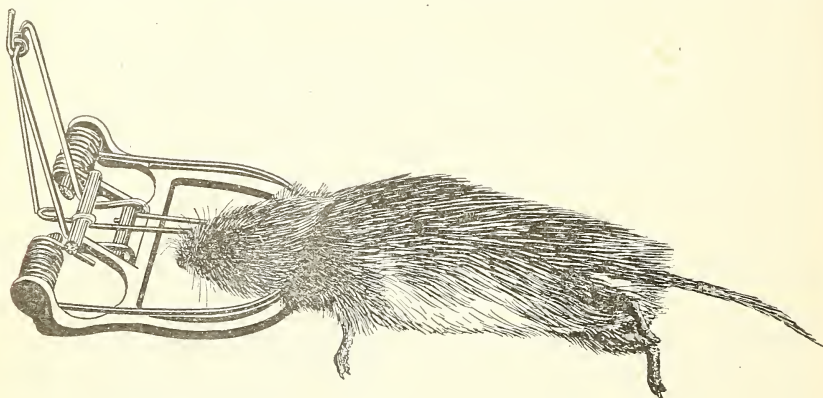


FIG. 2.—Field mouse caught in baited guillotine trap.

sistently and to look after the necessary large number of traps. When field mice are abundant it is essential to use many traps and to continue trapping for several weeks. Equipped with a hundred or

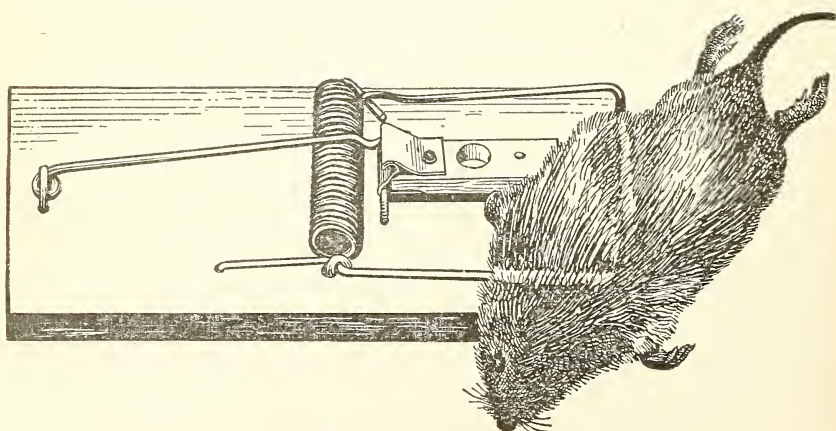


FIG. 3.—Field mouse caught in unbaited guillotine trap.

more effective traps, a good trapper should be able to make decided inroads upon the numbers of the pests, if not to practically exterminate them over a limited area.

Trapping has special advantages for small areas such as lawns, gardens, and vegetable or nursery pits and packing houses, where a limited number of mice are present, and wherever, for any reason, there are objections to the laying out of poison. As voles do not readily enter cage traps, simple wire traps of the guillotine order, in which mice are instantly killed, are the most effective (text figures 2 and 3).

Traps without bait may be set across the runs of the mice, where the animals spring them by coming in contact with the trigger, or they may be baited with oat or corn meal. For trapping pine mice an opening should be made in the underground tunnel large enough to receive the trap, which should be set across the bottom of the runway. The traps may be baited or not, but the opening should be covered.

CULTIVATION.

Thorough cultivation of fields tends to keep down the number of voles. Cultivation implies the destruction of weeds and all the annual growths that provide winter shelter for the animals. The mere plowing of a field badly infested by mice is sufficient to drive out most of them. However, as a rule the animals escape to adjoining fields and return to their old haunts when growing crops or weeds afford sufficient shelter.

The Scottish vole plague of 1892-93 originated in hill pastures, where heather, moss, and numerous grasses afforded abundant shelter. The outbreak on the border farms in 1876-77 occurred under similar conditions. The Thessalian vole plague of 1891 and 1892 apparently grew out of peculiar conditions of cultivation. The district visited by the mice is an extremely fertile one on the plains near Larissa. The lands are mostly in large holdings, the owners of which rent the fields to peasants who live in the villages. Owing to primitive methods of cultivation, each peasant has only a small tract. As the number of renters is small, a system of rotation is practiced which brings the same tracts into cultivation about once in three years, while two-thirds of the district lies fallow. In the fallow lands voles multiply until at times they invade the cultivated lands and ruin the crops.^a

While a high state of tillage does not always bring immunity from voles, it does much to lessen the danger of attacks from them. A system which regularly brings all the land of a district under the plow and permits little of it to lie unused will secure the greatest immunity from these pests.

^a Prof. T. Loeffler, *Centralblatt für Bakteriologie und Parasitenkunde*, vol. 12, pp. 1-17, July 5, 1892.

OTHER MECHANICAL DEVICES.

Mechanical methods of destroying voles have long been in use, and sometimes are effective. In some countries where the animals are abundant, considerable reliance is placed upon the efforts of laborers armed with spades and other digging tools and assisted by dogs. In this manner thousands are sometimes killed.

Trenching also is a favorite method of catching both mice and moles. Trenches a foot and a half deep are dug at intervals about the infested lands. They are wider at the bottom than at the top, or have perpendicular sides. The animals fall into these pits and are unable to climb out. Men and dogs regularly make the rounds and despatch the animals thus caught. This method was used effectively in Dean and New Forests in 1813 and 1814 and in the later vole plagues of Great Britain and central Europe.

Inundation with water and fumigation with sulphur have been employed to some extent in killing field mice. All these mechanical methods involve much labor and are slow and often expensive.

POISONING.

As the laying out of poison for wild animals is attended by danger to other animals and to human beings, it should never be intrusted to the ignorant or careless. In some countries the laying of poison is forbidden by law, and several of our own States have enactments regulating the practice or forbidding it. The majority of States have no legislation prohibiting the use of poison, and the matter is usually left to the judgment of the individual farmer, to whom attaches responsibility for any damage that may result through his carelessness.

STRYCHNINE.

All things considered, strychnine is the most satisfactory poison for field mice. Although a very deadly substance, it is less dangerous to handle than either phosphorus or potassium cyanide. Its extreme bitterness renders it less liable to be mistaken for a harmless drug. Nevertheless, every precaution should be taken in handling it. The strychnine salt most used commercially is strychnia sulphate. This is the best for poisoning purposes, since it is soluble in boiling water, while the alkaloid requires the presence of an acid for its solution. To disguise the bitterness of the poison when employed for rodents, sugar is used, or the strychnine may be mixed with its own bulk of commercial saccharine.

For poisoning field mice various baits may be recommended, such as wheat, oatmeal, and corn, among the grains, and seeds of various plants, as the tomato, dandelion, sunflower, and others. The bait should be soaked over night in a poisoned sirup, which may be prepared as follows:

Dissolve an ounce of strychnia sulphate in a pint of boiling water; add a pint of thick sugar sirup and stir thoroughly. The prepared sirup may be scented by a few drops of oil of anise or rhodium, but this is not essential. A half ounce of borax is said to keep the mixture from molding.

The above quantity (a quart) of sirup is enough to poison a half bushel of wheat or corn, but smaller proportional quantities of grain and sirup may be mixed as needed. If after thorough mixing the solution is not sufficient to wet all the grain, add a little water. After standing over night, if the grain is too wet, a little dry corn meal will take up the excess of moisture. If oatmeal is used as a bait, when the mass is wet throughout with the sirup, it may be used immediately.

Because of the danger of destroying native birds, such as quail, sparrows, and others, the poisoned bait should not be placed in exposed situations, but under shelters which will admit mice but exclude birds. Wide boards lying upon thin cross pieces of wood are excellent for the purpose. For pine mice baits may be placed in the underground tunnels without endangering birds. For other mice pieces of drain tile about $1\frac{1}{2}$ inches in diameter may be laid along the trails, and the baits inserted into the tiles with a long knife or spoon. Tiles are recommended by the French Minister of Agriculture, but old tin cans with flattened ends or small openings are excellent substitutes.

In winter the following plan is especially recommended for orchards and nurseries:

Cut small twigs from branches of apple trees (suckers are excellent for the purpose) and either dip them in the strychnine sirup or apply the sirup to them with a brush. Scatter the poisoned twigs near the trees to be protected. This plan is excellent for either field mice or rabbits, and it entirely obviates the danger of poisoning birds or domestic animals.

OTHER POISONS.

Among other poisons that have been recommended for the destruction of field mice are phosphorus, potassium cyanide, and various mineral poisons, including arsenic. The mineral poisons as a rule are less virulent than the others.

Phosphorus, when properly used, is an excellent though rather slow poison for rodents, a very small quantity producing death. It is, however, dangerous to handle both because of the liability of severe burns and because of the danger of serious conflagrations. Its use in the West to destroy ground squirrels frequently results in the burning of standing grain and in extensive prairie fires. For these reasons we do not recommend its use for poisoning mice.

Potassium cyanide is a most deadly poison, almost tasteless, and with no known antidote. It is therefore dangerous to man, and its general use for poisoning rodents can not be recommended. It is open to the further objection that upon exposure to air it rapidly decomposes and becomes less effective.

Among the mineral poisons that have been successfully employed in destroying field mice is barium carbonate. This substance is comparatively cheap, and is both odorless and tasteless, so that rodents do not detect its presence in food. Its action in the digestive tract of rats and mice is slow, but reasonably sure to produce death. Larger animals are not affected by small doses of the poison, such as would be put out to kill mice; and for this reason its use is attended with less danger than that of strychnine or arsenic.

This poison is usually administered in the form of dough made of four-fifths flour or meal and one-fifth barium carbonate. A little sugar is added to sweeten the mixture, and, if desired, a couple of drops of anise oil. The dough is cut into small lumps (the size of a large pea) for mice, but larger ones are required for rats. The poison may be fed also in moistened bread or oatmeal.

Although the advantages of barium carbonate as a rodent poison have been long known, it has recently been brought into prominence on account of successful experiments in destroying field mice with it made by Dr. Lorenz Hiltner, of Munich, Germany,^a and by E. Schri-baux in France.^b

Winter is the most favorable season for poisoning field mice. Summer poisoning is usually less successful, on account of the abundance of green food. Although the animals are active in nearly all kinds of weather, they move about more freely in winter when it is comparatively warm. For the best results, therefore, poison should be set out in the evening of rather mild days. Since mice usually work under the snow, it is useless to put out poison for them on the surface of the snow.

The importance of protecting birds during poisoning operations can not be too earnestly insisted upon. In France, in 1905, a great scarcity of birds, particularly partridges, was noticed in the departments of Vienne, Deux-Sevres, and Charente, which was attributed to the extensive use of poisons during 1904 to destroy field mice.^c

Says the editor of *Western Field*, of San Francisco, Cal.: "In two or three counties in this State—notably in that of Santa Barbara—the quail, dove, and song birds are being threatened with actual extermination from poison put out by farmers with the intent of killing off the ground squirrel pests. The poison has been scattered indiscriminately over wide areas, and reliable observers keep sending in reports of their finding thousands of dead birds of all kinds, victims of the squirrel bane."^d

^a *Praktische Blätter für Pflanzenbau und Planzenschutz*, vol. 1 (new series), pp. 112–116, November, 1903.

^b *Journal d'Agriculture Pratique*, vol. 9 (new series), No. 22, pp. 708–710, 1905.

^c *Journal d'Agriculture Pratique*, Sept. 14, 1905, p. 327 (quoting the journal *Temps*).

^d *Western Field*, vol. 8, No. 1, p. 57, February, 1906.

ADDITIONAL METHODS OF POISONING.

The following recipes and recommendations contain useful hints to farmers who for any reason do not wish to follow the recommendations already made:

To protect trees from mice we take blocks of wood 6 inches in length by 3 in diameter, and with a six-quarter auger bore a hole 4 inches in depth. Mix a dessert spoonful of arsenic with a quart of corn meal, or in that proportion, put one spoonful in each box prepared as above, and put it under each tree beneath the mulch. Renew the meal once or twice each year. This process is a sure protection.—Lewis H. Spear, in U. S. Agricultural Report for 1852, p. 153.

Different poisonous preparations have been used with effect on these vermin. The following are among the best:

Two ounces of carbonate of barytes, mixed with a pound of suet or tallow: place portions of this within their burrows or about their haunts. It is greedily eaten, produces great thirst, and death ensues after drinking. This is an effective poison, as it is both tasteless and odorless. Or,

Two ounces finely powdered arsenic, 2 ounces lard, 10 drops oil of rhodium, mixed with flour or meal into a thick dough, and pills of it scattered about the orchard and nurseries.—E. A. Samuels, in U. S. Agricultural Report, 1863, p. 272.

These animals (*M. agrestis*) had devoured the succulent flower stems of some hundred *Lobelia cardinalis* and the fleshy stems of Pampas grass (*Arundo conspicua*). After making a number of futile experiments, I noticed the animals feeding on dandelion seeds. Securing some ripe heads of dandelions and cutting off the down, I steeped them in a solution of strychnine and laid them in the runs of the voles. In a few days I had exterminated all of them from the garden.—D. Melville, in Annals of Scottish Natural History, January, 1893, pp. 41-42.

In the month of February half a ton of one-and-a-half inch drain tiles were laid down separately throughout the plantations and a teaspoonful of oatmeal was placed in each, which was soon discovered and eaten by the mice. Phosphorus paste was then added to the meal and latterly small quantities of arsenic. The plan succeeded perfectly, and in a very short time they were all destroyed.—Sir Robert Menzies, Rannock, Perthshire, Scotland.

A mixture of four-fifths flour and one-fifth arsenic is introduced by the aid of a small palette knife into the middle of a drain pipe with an internal diameter of about 3 centimeters ($1\frac{1}{4}$ inches), and this pipe is then put near the holes of the mice.—Recommended by the French Minister of Agriculture in a letter to the British Vole Commission of 1892.

I shell out pumpkin seed, grind it into meal, and mix with strychnine. This is put into a tomato or corn can, the sides bent flat, so that no other animal can get at the meal, and the can then laid on the side. It is a great success.—Method used by Fred. Noerenberg, Cascade Springs, S. Dak.

FUMIGATION.

Generally speaking, the various methods of fumigation for destroying field mice are unsuccessful. Nearly all the species have numerous burrows, and it is difficult to determine the occupied ones. To insure success, therefore, all the burrows must be fumigated, and the amount of labor and material involved makes the methods too

expensive. However, occasionally carbon bisulphid may be used to advantage, especially with pine mice. A little of the liquid is poured upon a piece of rag or other absorbent material and this pushed into the burrow, which at once should be closed with soil to confine the gas.

MICRO-ORGANISMS.

The efforts of Loeffler, Danysz, Mereshkowski, and other European bacteriologists to destroy field mice by means of infectious diseases have been partially successful, but as yet no disease appears to have been found that is really contagious. As long, therefore, as infection can be effected only by direct inoculation or through the food, the methods have little, if any, advantages over ordinary poisons.

The Biological Survey, cooperating with the Bureau of Animal Industry, is engaged in experiments with various micro-organisms for destroying field mice and other rodents, and practical results along these lines may yet be reached.

RECOMMENDATIONS TO FARMERS.

When conditions are unusually favorable for an increase of voles, the farmer should put forth all possible efforts to repress them. With cooperation among the farmers of a district serious losses may readily be prevented. The danger lurks outside of cultivated areas and in the swamps, forests, and waste places along fence rows and small brooks that harbor weeds and underbrush. It is by giving attention to these and by reducing to a minimum the extent of shelter for mice that the farmer can most successfully protect his crops.

A second important consideration is the protection of animals and birds that prey upon field mice. The farmer should by all means acquaint himself with the food habits of the various species of wild animals of his vicinity, to the end that he may distinguish friend from foe. Every farmer can do much in his community to help form an enlightened sentiment in favor of beneficial birds, mammals, and other animals.

PREVENTION OF INJURY TO ORCHARDS AND NURSERIES.

Injury to orchards and nurseries by field mice may generally be prevented by forethought and the exercise of ordinary care. Of first importance, always, is clean tillage. No grass or weeds should be left in or near the nursery. So well is this understood by the majority of experienced nurserymen that by clean tillage they secure practical immunity from the ravages of mice except in winters of deep and long-lying snow. If grass and weeds are destroyed in fence corners and waste lands near the nursery, complete immunity from mice ravages can be depended upon even in winters of deep snow.

Unfortunately, nurserymen can not control the lands which environ their trees, and when snow falls to a considerable depth prompt measures are sometimes necessary to keep mice from destroying them.

This can be accomplished most readily by dragging a heavy log or stick of timber several times around each block of trees, packing the snow so firmly that mice can not tunnel under it. If this precaution is taken promptly after the first snow fall, subsequent falls will require but little attention. Some nurserymen plow furrows on both sides of the trees, throwing up the soil in a ridge along the rows; but the expedient is of doubtful utility.

Much of what has been said about the nursery will apply as well to young orchards. Clean cultivation is equally important, and under no circumstances should matted grass be allowed around the trunks of trees or litter be permitted to accumulate in the orchard or along its borders. In case of heavy snows, dragging should be resorted to or the snow stamped down carefully around each tree.

In the absence of snow, a cleared space of about 18 inches radius about the trunk of each tree is enough to prevent damage. The surface of the cleared space should be as smooth as possible, as even clods of earth may afford shelter for mice.

If any part of the orchard is so located as to be subject to snow-drifts and mice are abundant in the vicinity, tree protectors should be used. These may be had of dealers for 60 to 75 cents per hundred or they may be made by the farmer. Those offered for sale are usually wood veneers of some sort. In California the wood of a yucca (*Yucca brevifolia*) is utilized for the purpose. Strips of wire cloth make excellent protectors, and tarred paper is a favorite with some horticulturists. The wire cloth or paper is cut into strips about 7 inches wide and at least 15 inches long. A strip is secured around each tree with wire or cord. Tarred paper should never be used on very young trees, and when used on others should not be left in place during the summer, since it may injure the growing tree.

Various paints and washes have been recommended to prevent attacks of mice and rabbits in orchards. The majority of these are without merit and some of them are liable to kill young trees. Some of the washes require renewal after every hard rain. In experiments with a wash of whale-oil soap, crude carbolic acid, and water, for apple trees, it was found that in about forty-eight hours the carbolic acid had so far evaporated that mice renewed their work upon the bark. Blood and grease, said to give immunity from rabbit attacks, would invite the attacks of field mice.

Reports recently received by the Biological Survey seem to indicate that the ordinary lime-and-sulphur wash, recommended for the winter spraying of trees to destroy the San Jose scale, is an effective preventive of the attacks of both mice and rabbits. Personal observations during the winter of 1906-7 indicate that this claim is well founded. Several correspondents state that they have tried the wash successfully, and the matter is worth further investigation. The wash is very cheap (from 1 to 2 cents a gallon when prepared in 45 to 50

gallon quantities) and is easily applied to the trunks of trees either in the form of a spray or by the use of a brush. One thorough application in November would probably be effective for the entire winter. The ingredients of the wash are 20 pounds of unslaked lime, 15 pounds flowers of sulphur, and water to make 45 to 50 gallons. The mixture should be boiled in an iron kettle at least an hour and applied to the trees while warm.^a

Winter mulching of trees is dangerous, unless the neighborhood is known to be free from mice. Mulch containing straw may be placed in the orchard in spring, but it should be removed before the approach of cold weather. Fine, thoroughly rotted manure may be used in the orchard with but little danger. Lime or ashes about the trunks of trees has some value in keeping off mice, but clean cultivation is equally or more effective.

REMEDIES FOR INJURED TREES.

When trees are girdled by mice, portions of the inner bark (cambium layer) are often left, partly covering the hard wood below. If sunlight and wind have free access to the injury, the remaining bark dries up and the tree dies. If light and air are excluded, new bark will form and the wound quickly heal over. To facilitate the healing process, it is important that wounds be covered as soon as possible. As a covering for wounded trees, wax, paint, strips of cloth, clay, and cow dung have been recommended, but none of them has any advantages over fresh, loose soil. Unless the ground is frozen, this is always available and easily applied to wounds near the ground. All that is needed is to mound up the soil about the trunk of the tree high enough to cover the wound. Allowance should be made for settling of the soil, and the covering should remain during the entire summer. Plate VIII shows trees 5 inches in diameter which were completely girdled by mice in December, 1903. Soil was heaped about the trunks in January, 1904, and allowed to remain until May, 1905, when it was removed and the photographs made. New bark completely covered the wounds, leaving slight visible scars.

If large fruit trees are injured high up, as sometimes happens when snow is drifted about them and mounding up the soil is impracticable, there are other means of saving them. If the injury is not too extensive, grafting wax should be applied to the wounds and the tree wrapped with strips of cloth. If, however, the cambium be eaten through over considerable surface, bridge grafting may be resorted to.

Bridge grafting is not difficult. It consists in bridging over the girdle of eaten bark by means of scions or small twigs of the same kind of tree. The injured bark at the top and bottom of the wound should be cut back to live, healthy tissue and small clefts or notches

^a See Yearbook U. S. Dept. of Agriculture, 1906, pp. 429-446. Lime-sulphur Washes for the San Jose Scale.

made in it. The ends of the scions are then cut to fit these notches, the scion itself being left slightly longer than the span of the injury, so that they may be sprung into position and held firmly. The cambium layer of tree and scion should meet over as much surface as possible. Some operators use a chisel to cut the notches and a small nail or tack at each end to hold the scion in position. The last step is to cover all exposed cut surfaces with grafting wax or to bind all with waxed cloth so as to exclude air until the scions are firmly united with the tree.

If young orchard trees are but slightly injured a covering of grafting wax may be applied with good results, though a covering of soil is equally effective. The usefulness of paints for damaged trees depends both upon the stage of growth and the composition of the paints. Some are said to kill trees if applied in the spring. Coal tar will do the same, as the writer learned by costly experiment. Pine tar has been highly recommended for wounded trees, but it has been known to kill young peach trees to which it was applied to keep away mice.

For nursery stock badly injured by mice there is no remedy. When the injury is slight the wounds may be covered with wax or soil and will heal over in a season, delaying sale for a year. This applies to both deciduous trees and evergreens. In the case of young trees, when the injury is considerable the tops may be cut out and new ones grown more quickly than fresh stock, but this is possible only when the wounds are well above the original graft. In the case of valuable or rare sorts bridge grafting may be resorted to, but for ordinary stock it is cheaper to pull up the injured trees and grow new ones.

SUMMARY.

Field mice, because of their small size, secretive habits, and great fecundity, often become a menace to farm and orchard crops in many parts of the country. In the Old World, as well as in America, corrective measures begun after a plague of the animals is in full progress have usually proved ineffectual. Preventive measures, if carefully carried out, are sufficient to avoid serious losses.

Among the more important measures for preventing ravages by field mice are the following:

1. Protection of the natural enemies of field mice, particularly owls, most hawks, shrikes, snakes, skunks, badgers, and most species of weasels.
2. Elimination of the breeding grounds of field mice by draining swamps and cleaning waste places that afford the animals harborage.
3. Periodic plowing of grass and other lands for the rotation of crops.
4. Clean cultivation of corn and all other crops, and especially of orchards and nurseries.

5. Clean mowing of grass lands and permanent meadows, so that no old grass is left over winter.

6. Careful burning about orchards and gardens of weeds, trash, and litter of all kinds that may serve the animals for winter shelter.

7. When necessary, the burning of dead grass in meadows and pastures. This, however, should not be delayed till late spring, when ground birds are nesting.

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